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Natural Herbicides and Plant Growth Regulants in Canola and Sweetclover Residues

Conducted by
E. Coxworth, K. Foster, H. Austenson,
W. Mason and A. Mair

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EXECUTIVE SUMMARY AND FARMER VERSION.

NATURAL HERBICIDES AND PLANT GROWTH REGULANTS IN CANOLA AND SWEETCLOVER RESIDUES

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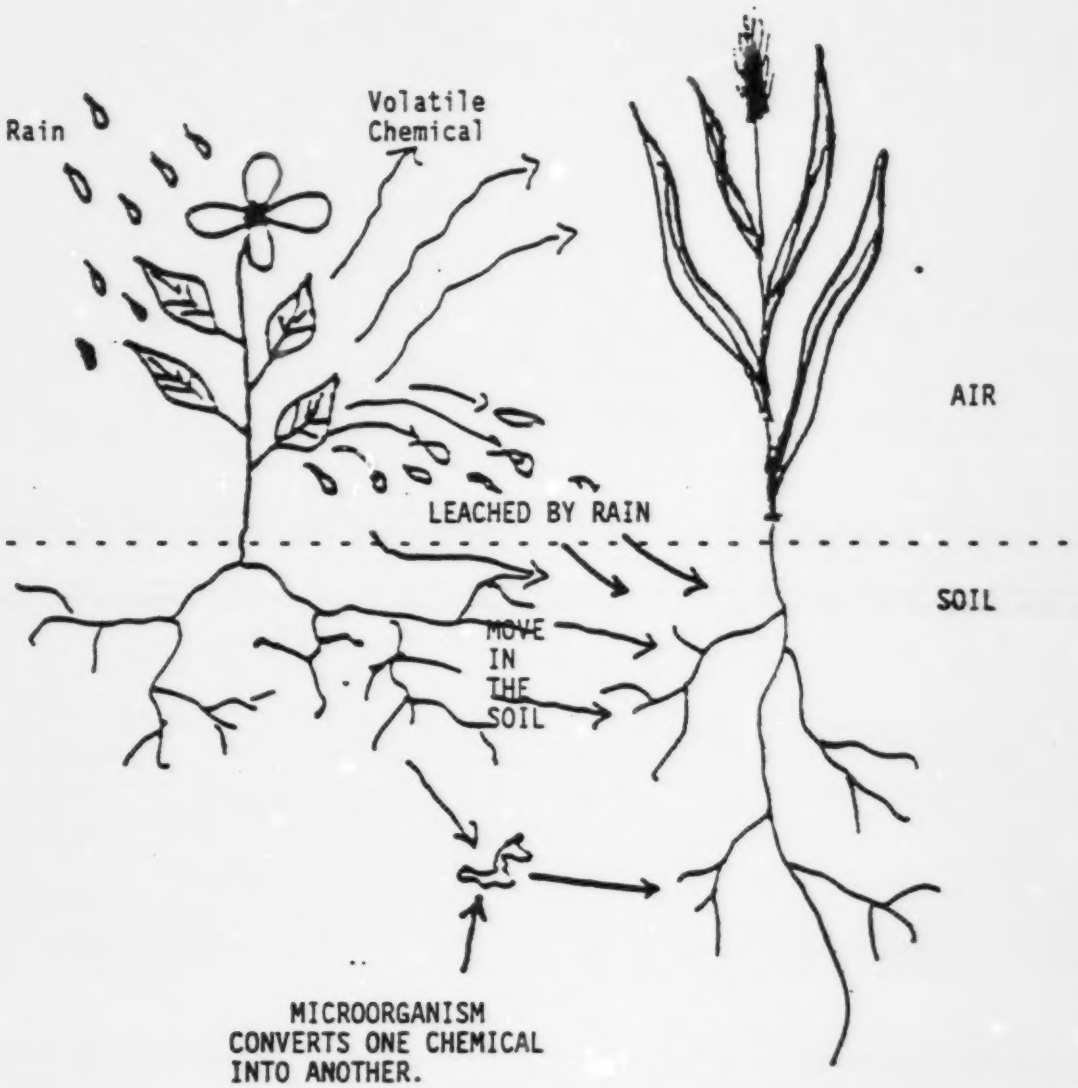
(As reported in the farm magazine Synergy, Winter 1990)

A number of plants has been found to contain naturally occurring herbicide-like chemicals. Under the appropriate circumstances these chemicals can leak out of the plant and can control the growth of (or even kill) other plants growing close by (see Figure 1). This effect is called allelopathy. In the past 10 years plant scientists have been studying this effect to determine whether it could be used for controlling weeds. The United States Department of Agriculture (USDA) has supported a number of such studies at American universities and research institutes.

The USDA's interest in allelopathy is based partly on the problems with existing methods of weed control. Herbicides can be expensive and in some cases weeds have built up resistance to particular herbicides. For example, green foxtail, wild oats and kochia have been found to have developed resistance to some herbicides, particularly where the same herbicide has been used year after year on the same field. On some porous soil types in the United States, certain herbicides have leached out of the top soil and into ground water. Use of these herbicides is now restricted in some states and on certain soils because of this problem. Tillage methods of weed control can cause problems too. Tillage can leave the soil exposed to wind and water erosion, and can

Figure 1. Allelopathy: One plant influencing the growth of another by the release of a natural chemical substance into the soil or air.



OTHER FORMS OF INTERFERENCE:
. SHADING
. COMPETITION BY ROOTS FOR NUTRIENTS AND MOISTURE

dry out the soil. The terrible dust storm of May, 1989 in Saskatchewan showed how vulnerable bare, unprotected soils can be to wind erosion.

Our studies were financially supported by the Canada-Saskatchewan ERDA agreement on agriculture, the Saskatchewan Research Council and the University of Saskatchewan. We wanted to determine whether the crop residue of canola, or the killed young growth of sweetclover or canola (used like cover crops), contains natural herbicides, and whether these could aid in the control of three weeds: green foxtail, kochia and wild oats. By leaving the crop residue or killed cover crop on the soil surface we hoped also to leave the soil well protected against wind and water erosion.

Crops Residues with No Weed Suppressing Effect

We did not find any natural herbicide effect in the crop residue from mature canola, harvested for seed. Neither the straw nor the chaff had any weed suppressing effect. In fact, the mulching effect of the crop residues kept the soil surface moist and encouraged the growth of the weeds. However, in growth room experiments, very high rates of application of mulches tended to suppress weed growth, but the effect was a physical one, the weeds seeming to have trouble emerging and growing from under the heavy mulch covering.

Sweetclover, used as a cover crop, and left standing after being killed by a herbicide, did not have much inhibitory effect on weeds. The variety Yukon, which contains the natural plant chemical called coumarin, was slightly more inhibitory of weeds than the variety Norgold, which has lower levels of coumarin. We planted both winter wheat and spring wheat into the killed sweetclover cover crop residue,

and found that yields of both were higher after Yukon sweetclover than after Norgold sweetclover. Other studies in North Dakota have shown, however, that yields after sweetclover are better if the clover is cultivated into the soil rather than left standing as a desiccated cover crop (Meyer, 1987).

Crop Residue which did have a Weed Suppressing Effect

In contrast to these results, young canola and mustard plants were found to have potent weed suppressing abilities. We followed initial experiments in the growth room with field trials, and found that killed young canola or mustard plants severely inhibited the growth of kochia or green foxtail. The canola or mustard plants were killed either by chopping up the top growth and spreading it around the young growing weeds, or by killing the cover crops by a light application of the herbicide 2,4-D.

The method we used in the field experiments simulated what a farmer might do if he or she were using young canola for a cover crop for fallow: The canola was seeded first. After one week the weeds were planted between the rows of emerging canola, to simulate the germination of weeds after an early planted cover crop. After 38 days, when the canola was about 20 cm (8 inches) high and had formed a complete leaf canopy, it was killed either by chopping it and spreading it around the weeds, or by wick applying a low dose rate of 2,4-D herbicide. Two weeks after the canola cover crop was killed, the weeds were harvested and their number and weight per unit area determined. For comparison, the weeds were also planted in plots without canola. Some of these control plots had poplar shavings applied around the weeds to test the

effects of a mulch known not to contain any natural herbicides. In 1989 we also tested the effect of shading only on the growth of the weeds, by covering some of the control weed plots (no canola) with lath and plastic ribbon boxes which reduced the levels of light reaching the weeds by at least half. All the treatments were replicated and randomized so we could test the significance of any weed suppression that we found.

The results from these two years of trials are shown in Table 1.

Table 1. Effect of canola cover crop on the growth (weight per unit area of three weeds.

Weed	Treatment	1988	1989
		weeds weight as a % of control	
Green Foxtail	Chopped canola	1.5 a	34.1 a
	* Canola killed with 2,4-5	0.6 a	22.7 a
	Control (weed only)	100.0 b	100.0 b
	Control plus poplar mulch	166.1 c	104.0 b
	Control plus shading	ND	31.1 a
Kochia	Chopped canola	1.1 a	2.5 a
	Canola killed with 2,4-D	0.2 a	4.3 a
	Control (weed only)	100.0 b	100.0 c
	Control plus poplar mulch	115.9 b	80.4 b
	Control plus shading	ND	15.6 a
Oats (Tame oats to mimic wild oats)	Chopped canola	12.4 a	17.2 a
	* Canola killed with 2,4-D	4.7 a	12.3 a
	Control (weed only)	100.0 b	100.0 c
	Control plus poplar mulch	108.0 b	122.9 d
	Control plus shading	ND	56.4 b

ND = not determined
Note: the smaller the number the better the control of the weed.
* Note: The 2,4-D applied to the canola would not directly effect the foxtail or oats.

Numbers followed by the same letter within a column and within a weed species are not significantly different at P=0.05 NDMRT.

The years 1988 and 1989 offered a complete contrast in growing conditions. In 1988 the spring and early summer were so hot and dry that we waited until late June to plant the canola and the weeds. Then in July the weather improved; temperatures were only slightly above normal and rainfall slightly below normal. In August the weather was cooler and rainier than normal. The canola established well and formed a canopy over the weeds. Killing the canola gave excellent control of green foxtail and kochia, and good control of oats (simulating wild oats). In 1989 we waited until late June to plant the canola and then the weeds to repeat the comparison with 1988. But July and early August in 1989 were hotter and drier than in the previous year. The weeds were able to compete with the canola better under these conditions, particularly green foxtail. Control of kochia was still very good in 1989, but control of oats was slightly poorer, and of green foxtail only fair. In both years the degree of weed control by the canola was statistically significant.

The lesson we have learned from the 1989 results is that it is important to get the canola cover crop well established (e.g. early spring) before the weeds emerge in order to obtain good weed control. This needs to be tested in further field trials. The 1989 results indicated that shading of the weeds can reduce growth significantly also, another reason to get the cover crop established early.

Other experiments in the growth room have shown that chemicals released by the killed canola or mustard are likely responsible for at least some of the weed suppressing effects we have found. This chemical effect seems to be integrated with other weed suppressing effects such as shading and competition for nutrients and moisture between the cover

crop and the weed. A number of other experiments need to be carried out to measure the relative importance of the different effects.

Wheat was grown in 1989 on the plots from the 1988 cover crop experiments. No differences in yield were found, showing that there were no negative effects of the cover crops carrying over from 1988 to 1989.

Where Do We Go from Here?

The best situation to test these very promising results would, we think, be to use canola as a cover crop for summer fallow. Canola or mustard are cheap to seed. If they were planted early and killed by mulching or by 2,4-D when they were still young in late June or early July, the moisture loss from the cover crop growth might be regained from the mulch effect and snow trapping over the following winter. Many other experiments and field trials are needed to measure the effect on many other weeds and on other following crops. We do not know whether any of the natural herbicides being released from the cover crop into the environment have a negative effect on man or other living creatures; this will also need to be examined.

Canola or mustard might be useful in situations other than as a cover crop for fallow. Frank Forcella at the USDA research centre in Morris, Minnesota found that young canola could be used as an over-wintered cover crop to kill weeds in a continuous zero-till corn production system. The spring-growth of the canola was killed with 2, 4-D just before the corn was zero-till planted. Corn yields were as good as the control, weed control was nearly as good as the conventional system using several herbicides, and overall weed control costs were

one-half those of the conventional system (Forcella, 1986). We used some of his ideas in developing our own experiments here in Saskatchewan.

Farmers attempting to reduce or eliminate herbicides may find such cover crops of use to them in the future. As far as we can determine, the use of such natural herbicide containing cover crops, once they are proven safe, would not contravene the guidelines for organic crop certification, provided mulching was used to kill the cover crop.

For farm situations where herbicides are used, combinations of herbicides with these cover crops might be less likely to lead to inadvertent selection for weeds with herbicide resistance. It is unlikely that the weed population would contain plants with the genes for both allelopathic chemical resistance and herbicide resistance.

We stress that our results are in the early stages of development into farm proven systems, although the initial results are very encouraging. We are looking forward to further studies to develop sustainable cropping systems involving natural herbicide containing cover crops.

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INTRODUCTION AND SUMMARY

The general objective of this research is to attempt to develop cropping systems utilizing the effects of natural herbicides (allelopathic chemicals) in crop residues and green manure crops that would maximize the benefits (e.g. better weed control) and minimize the negative effects (e.g. reduced yield of the following crop). This would be investigated in zero and minimum tillage winter wheat and spring wheat production systems: canola-winter wheat, and sweetclover-winter wheat, or canola-spring wheat, and sweetclover-spring wheat.

The specific objectives of the project are:

1. Through field trials, test for the presence of natural herbicides in cultivars of the following crops grown in western Canada: canola (Brassica campestris), and sweetclover.
2. Test sweetclover types with significantly different levels of natural herbicides to measure differences in weed control and effects on the yields of following crops. High and low coumarin lines of sweetclover would be tested as a preceding desiccated green manure cover crop to winter wheat.
3. Measure the effect of removal of canola chaff, during canola harvest, on weed control (including volunteer canola), and on the subsequent growth and yield of winter wheat. In the same field trial, canola straw would be applied at three different rates (e.g. 2, 5 and 8 tonnes per hectare) as a surface mulch in a zero tillage planting of winter wheat. The study will examine the effects of different rates of canola straw on the emergence, plant growth and seed yield of the winter wheat, and on any weed control benefits.

4. Test the effect of application of very low levels (non-lethal) of herbicide (e.g. glyphosate) on production of natural herbicides (e.g. phenolics) in sweetclover. This would be done in a greenhouse study. This study was replaced in 1988 and 1989 with the study on the effects of killed young canola plants on suppressing weeds, since the latter was concluded to have a much higher practical importance to farmers.

Field experiments with sweetclover (Chapter 1)

Although yields of Norgold (low coumarin) and Yukon (high coumarin) sweetclovers were similar, yields of winter wheat and spring wheat were markedly higher after Yukon. There was a noticeable mulch effect of sweetclover residues. Removing all residues reduced yields of wheat. Putting on three time the normal amount of sweetclover residue increased yields substantially. These plots were severely infested with flaxweed, and the sweetclover residue was not able to control this weed. However, visual comparisons suggested that Yukon (high coumarin) gave better control of weeds than Norgold (low coumarin). Thus the initial field results suggest that the high coumarin sweetclover variety (Yukon) may be a better green manure crop than the low coumarin variety (Norgold).

The high coumarin variety (Yukon) had 2-3 times the amounts of coumarin as the low coumarin variety (Norgold).

Growth room studies with sweetclover (Chapter 2)

The results from this study tended to confirm the field trial. The Yukon (high coumarin variety) sweetclover tended to have a more marked effect on weed suppression than Norgold (low coumarin). The mulch

effect, i.e., physical effect, seemed to be larger and more significant, than the chemical effect. Thus the highest rate of mulch (sweetclover or poplar shavings) had the biggest effect. Further experiments are needed to test the effect of time delays (as would occur in the field) and planting of crops on weed suppression and crop yield. Experiments (field) in North Dakota strongly support the conclusion that incorporation of green manure legume residues results in much better yield responses of a following cereal crop than surface desiccation.

Effect of canola straw and chaff on wheat production and weed suppression (Chapter 3)

Winter wheat yields were positively affected by the amount of canola chaff but not significantly by straw. The highest rate of canola chaff, evenly spread, gave the highest yield of following winter wheat.

With spring wheat, both the rate of canola chaff and canola straw positively affected wheat yields, with the highest canola residue rate giving the highest yield of following wheat.

Weed populations were low in this experiment, although there were substantial number of volunteer canola plants.

Given the positive effects of residues rates on yields, the experiment was to have been repeated in 1987-88. However the extreme drought in May and June of 1988 resulted in crop failure. This study was then replaced with microplot studies on the effects on killed young canola on suppressing weed growth (see Chapter 5 and Chapter 6).

Growth room studies on the effects of canola crop residues on weeds (Chapter 4)

The main effects appeared to be due to physical factors, e.g. rate of mulch applied, rather than chemical effects related to the nature of the mulch used. Canola straw and chaff were no better than poplar shavings in controlling weeds. Incorporation of the residue had a greater benefit than leaving the residue on the surface, although the effects were not large. The plants in the growth room study were watered regularly, so any benefits of surface mulches in saving soil moisture were not observable.

Effects of young canola and mustard plants on kochia weed growth (Chapter 5)

Given the lack of chemical effect on mature canola straw and chaff it was important to check the effect of young canola plants, since previous studies by other authors indicated that young plants were potently allelopathic. Young canola and mustard plant residues were tested by us and found to be very toxic to kochia (dicot weed) germination and early growth. The effect on green foxtail was tested also to follow up this promising lead. Large reductions in weed growth were found, similar to the results with kochia. One possibility is to exploit this effect for chem fallow, i.e. use killed young canola or mustard plants for a green manure chem fallow system, where the canola or mustard plants act as mulch for soil erosion control and a source of chemicals for weed control. Field experiments (micro plots) were conducted in 1988 and 1989 to test this possibility. In the continuation of the growth room studies, repeated experiments confirmed that both

mustard and canola reduced growth of kochia or green foxtail. Over 90% reduction in weed growth was achieved. Some of the toxic effect of mustard was in volatiles, while no volatile toxins were found in canola. Canola might therefore be safer to use, until more is known about the mammalian toxicity of the allelopathic chemicals in young mustard and young canola.

Effects of young canola plants in the field on the growth of kochia, green foxtail and oats (mimicking wild oats) (Chapter 6)

Micro plots (1 m^2, replicated) studies were carried out in 1988 and 1989 to extend the growth room studies, described in Chapter 5, to field situations. In 1988 seeding was delayed until late June to avoid the drought. Canola was planted in micro plots, and the test weeds (kochia, green foxtail or oats (to mimic wild oats)) planted a few days later to simulate a field situation with an early seeded cover crop where the weeds emerged after the cover crop had become established.

In 1988 excellent control (98% or more) of kochia and green foxtail was obtained, and good control (up to 95%) of oats. In 1989, control of kochia was again very good (95%) but oats were only fair (88%) and green foxtail less (77%). In 1989 we waited until late June to plant the canola cover crops, to mimic the season used in 1989. However, in 1989, July was hot and dry, compared to July of 1988, and the canola did not grow as well, while the green foxtail and wild oats did grow well. We concluded that canola grown as a cover crop should be established as early as possible, so as to get as good a head start as possible on the weeds. This would also allow the cover crop to be killed earlier in the

season, so more moisture could be stored. The comparison of the two years field results are shown in the executive summary.

Wheat yields in 1989, after the 1988 cover crop study, were not affected by any of the treatments, indicated that were no negative growth effects of the cover crops carried over into the following year.

CHAPTER 1

NATURAL HERBICIDES AND PLANT GROWTH REGULANTS IN SWEETCLOVER RESIDUES

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I 1985-1987 Project

During 1985 two four acre fields of sweetclover were established. One field was seeded to a high coumarin type (c.v. Yukon) while the other variety was a new lower coumarin variety (c.v. Norgold). During 1986 the study was statistically set up in a Randomized Complete Block Design replicated three times and involving the following six treatments for each variety.

Plot #	Treatment
1	Desiccate sweetclover* at 1/4 full bloom using Glyphosate at 708 gai/ha.
2	Desiccate sweetclover* at 1/4 full bloom using 2,4-D at 560 gai/ha.
3	Desiccate sweetclover* at 1/4 full bloom using 708 gai Glyphosate/ha tank mixed with 2,4-D at 560 gai/ha.
4	Desiccate sweetclover at 1/4 full bloom using Glyphosate at 708 gai/ha tank mixed with 2,4-D at 560 gai/ha. Following spraying wait 14 days, then cut top growth off at ground level and remove.
5	Desiccate sweetclover at 1/4 full bloom using Glyphosate at 708 gai/ha tank mixed with 2,4-D at 560 gai/ha. Following spraying wait 14 days, then cut top growth off at ground level and remove. Add sweetclover back at a rate of 7.4 tonnes/ha.
6	Desiccate sweetclover at 1/4 full bloom using Glyphosate at 708 gai/ha tank mixed with 2,4-D at 560 gai/ha. Following spraying wait 14 days then remove top growth at ground level. Add sweetclover back at a rate of 14.8 tonnes/ha.

Each of the above treatments was arranged as a split plot with half seeded to winter wheat (c.v. Norstar) on September 5, 1986 and the remaining portion seeded to spring wheat (c.v. Katepwa) on May 20, 1987.
* Amount of above growth sweetclover biomass was 3.7 tonnes/ha.

In order to establish a successful weed density a mixture of weed seeds (10 broadleaf species) were broadcasted (October 1986) at a rate of 6 kg/ha on the plot area. This proved to be a mistake as fall moisture conditions and other related factors were ideal to cause an extremely dense growth of Flixweed (Descurainia sophia). This weed problem, combined with poor soil moisture, made spring seeding (c.v. Katepwa) and successful crop establishment difficult. Following spring planting the crop lacked uniformity. It was felt this variability was too high to allow any further evaluation relating to the allelopathic effect of the sweetclover.

The study was, however, monitored and the resulting grain yield (Table 1.1) and plant heights (Table 1.2) were recorded at harvest.

Table 1.1. The effect of sweetclover management and variety on grain yield (kg/ha) of two wheat cultivars.

Treatment #	Katepwa		Norstar	
	Norgold[1]	Yukon[1]	Norgold[1]	Yukon[1]
	- - - - - - - - sweetclover - - - - - - - -			
1	469	725	1160	1332
2	269	412	1145	1433
3	592	439	1698	1840
4	208	203	1541	1596
5	130	345	828	1180
6	719	1511	1078	2049
$\bar{x}$	398	606	1242	1572

[1] Norgold sweetclover = low coumarin variety
Yukon sweetclover = normal coumarin variety

Table 1.2. The effect of sweetclover management and variety on plant height (cm) of two wheat cultivars.

Treatment #	Katepwa		Norstar	
	Norgold[1]	Yukon[1]	Norgold[1]	Yukon[1]
	- - - - - - - - sweetclover - - - - - - - -			
1	55.4	56.9	57.9	61.3
2	41.0	48.9	59.2	61.6
3	61.6	51.3	65.6	69.6
4	48.6	46.4	64.1	66.7
5	48.1	51.9	53.9	58.3
6	63.5	72.4	56.1	62.7
$\bar{x}$	53.0	54.6	59.5	63.4

[1] Norgold sweetclover = low coumarin variety
Yukon sweetclover = normal coumarin variety

The value of a surface mulch in reducing soil moisture loss by evaporation was very evident in the spring wheat (c.v. Katepwa) plots. Treatments which had the sweetclover residue removed following desiccation (Treatment #4) were the least efficient in producing grain (Table 1.1). The merit of adding additional plant material was most noticeable in Treatment #6 where in excess of 14 tonnes/ha of residue was returned to the plot. These treatments (both varieties of sweetclover) produced double the average grain yield.

It would appear that with Norstar and Katepwa plot grain yields and plant heights were greater where the treatment involved Yukon sweetclover. While no plant counts were done it was visually apparent that the high coumarin sweetclover (c.v. Yukon) had lower weed densities than the low coumarin (c.v. Norgold) plots. Establishment and ground cover between these two varieties of sweetclover was equal.

II 1986-1988 Project

An expanded version of the above project was established with sweetclover being seeded on May 20, 1986 (attachment). The clover germinated and grew well during the 1986 season. On June 25, 1987 the required desiccation treatments were done while residue spreading was left until July at which time sweetclover dry matter yields were also determined. The study was arranged in a similar split plot design to the 1985-1987 trial with winter wheat being seeded on September 12, 1987, and plant counts being taken on October 16, 1987.

III Coumarin Content of Sweetclover Varieties

The high coumarin content sweetclover variety (Yukon) and the low coumarin variety (Norgold) were field sampled in 1986 and 1987 using second year sweetclover from the 1985-1987 and the 1986-1988 projects. Samples were taken in mid-bloom in 1986, and in late bloom in 1987. Whole plants were cut in the field, immediately frozen in liquid nitrogen in the field, and taken to the laboratory for storage in a deep freezer.

A number of subsamples were taken to the Agriculture Canada Research Station in Saskatoon where they were analyzed for coumarin by a high pressure liquid chromatography (HPLC) procedure.

Samples of fresh frozen sweetclover or of dried sweetclover were extracted with solvent (Cooper et al., 1981), the extract semi-purified, and the extract then analyzed by HPLC (Bassendowski, 1988).

Results are shown in Table 1.3.

Table 1.3. Coumarin content of sweetclover forage samples (high and low coumarin lines) in 1986 and 1987 (second year clover in both cases).

Material	Coumarin (% of DM)			
	Extraction of fresh frozen clover		Extraction of air dried clover	
	Average	Range	Average	Range
Yukon[1] 1986	0.28	0.14 - 0.39	0.32	0.30 - 0.35
Norgold[1] 1986	0.10	0.09 - 0.14	0.14	0.11 - 0.16
Yukon[2] 1987	0.10	0.08 - 0.12	0.13	0.13 - 0.14
Norgold[2] 1987	0.05	0.05 - 0.06	0.09	0.06 - 0.11

1 Harvested 26 June, 1986
2 Harvested 10 July, 1987

The fresh samples were quite heterogeneous (different proportions of leaves and stems) and this is reflected in the wide range of coumarin values found. The air dried samples had higher percentages of coumarin than the frozen which was unexpected given the reported volatility of coumarin. The high coumarin variety (Yukon) has 30% to 280% more coumarin than the low coumarin variety (Norgold) depending on the crop year and sample variability.

The effect of climate and stage of maturity at desiccation on the coumarin levels in high and low coumarin sweetclover may need to be measured if further testing confirms that coumarin has a significant effect on weed control.

Appendix - SRC-U of S Allelopathy study, Kernen Farm, 1987.

Treatment	Description
1	Cut sweetclover for forage, remove material and apply 1 ton/ac (dry matter basis) sweetclover.
2	As above only apply 2 ton/ac.
3	As above only apply 3 ton/ac.
4	As above only apply 4 ton/ac.
5	Desiccate sweetclover (Paraquat + Dicamba) and leave stand.
6	Cut sweetclover for forage and remove material from plot. Any secondary growth should be cut and removed also. Stubble to be left intact.
7	Work sweetclover down as a green manure crop. Reworking to control any secondary growth may be required.
8	Conventional fallow.
9	Desiccate sweetclover (Paraquat + Dicamba) and leave stand intact. Remove ground material from plots 21 days after herbicide application. Standing stubble to be left intact.
10	Cut sweetclover for forage and remove above ground material. Apply 1 ton/ac of inert material.
11	As above only apply 2 ton/ac.
12	As above only apply 3 ton/ac.
13	As above only apply 4 ton/ac.

- Cut sweetclover for forage when crop is in approximately 50% bloom.

- Each of the above treatments is to be arranged as a split-plot with half seeded to winter wheat (fall 1987) and half seeded to spring wheat (spring 1988). The study is to be replicated 3 times.

- Desiccation is to be done where required with Paraquat at 400 gai/ac with Dicamba added to the tank mix at the rate of 115 gai/ac.

- The entire study is to be sprayed with 2,4-D in late fall at a rate of 170 gai/ac.

- Broadcast weed seeds in the fall of 1987 following the spraying for winter annuals.

CHAPTER 2

GROWTH ROOM STUDIES ON THE EFFECTS OF SWEETCLOVER RESIDUE ON WEEDS

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Experiment

This study was conducted to determine the effect of placement (on soil surface or incorporated) and rates (1.5, 3.0 and 6.0 t/ha) of sweetclover residues on weed populations and winter wheat emergence and early growth. Poplar shavings (known to have no allelopathic effect) were used as a control to test the mulch effect devoid of allelopathic interactions.

Materials and Methods

Ninety-five, 17.5 cm plastic pots were lined with plastic bags and filled with 1400 grams of soil. To 400 grams of soil half of the residue treatment was added, and mixed thoroughly. For the non-residue treatments, and treatments receiving only surface residues, 400 grams of soil was used. This was placed on top of the 1400 grams of soil in each pot and lightly compressed. Twelve winter wheat seeds were placed on the surface towards the centre of the pot, and twelve de-awned wild oat plants were placed around the outer edge of the pots. An additional 400 grams of soil had 3 grams of mixed weed seeds added, and the remaining half of the residue treatment thoroughly mixed throughout and placed on top of each pot. Soil and weed seeds were used for the no residue and surface residue treatments, and canola straw and chaff or poplar shavings were placed on the surface for these treatments. Five replicates of each of the following treatment combinations was prepared.

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[1] Present address: Safer Chemicals, Victoria, B.C.

Residue	X	Rates	X	Placement
Yukon (before desiccation)		1.5 t/ha (3.8 g/plot)		surface only
Norgold (before desiccation)		3.0 t/ha (7.6 g/plot)		incorporated only
Poplar shavings		6.0 t/ha (15.2 g/plot)		
No residue				

Each pot was then watered to 80% of field capacity by weight, and maintained by watering every second day. The residues used had been air dried, but not oven dried or chemically desiccated. The experiment was started on July 29, 1987 for harvest during the week of either August 24 or August 31. Nutrient solution (20-20-20) was added August 5, 1987 and August 19, 1987. Harvesting of the pots was done on September 2. At this time plant numbers, and fresh weights were taken. Dry weights were taken at a later date when drying was completed. Drying was done at a temperature of 30-35°C.

Analysis

A factorial analysis of variance (control excluded) was done on the experiment as well as an analysis of variance where the experiment was considered to have 13 treatments in a completely randomized design. The control (no residue) is considered to be the thirteenth treatment. Student Newman Keuls tests were done also, to test for significance between means. Replication 4 was eliminated on both analyses because of missing data.

The factorial analysis of variance of the sweetclover experiment showed several tendencies, which were seen previously in the canola

experiment* However, these tendencies were less predictable and more variable than in the canola experiment.

The treatments Yukon versus Norgold versus poplar shavings significantly affected numbers of wheat plants, fresh weight of weeds, dry weight of weeds, numbers of cruciferae, dry weight of cruciferae, dry weight of chenopodiaceae, and the dry weight of wheat. Dry weights of wheat, numbers of wheat plants, fresh weight of wheat, number of weeds, and number of crucifeae were significantly lower for the Yukon sweetclover treatments. Norgold is the low coumarin sweetclover variety, while Yukon is a variety containing higher levels of coumarin. Table 2.1 showing the number of wheat plants, is typical of the previously discussed dependant variables, which were negatively affected by Yukon sweetclover.

Table 2.1. Average number of wheat plants for the three treatments.

Treatment	Average number of wheat plants
Norgold sweetclover	7.8
Poplar shavings	7.7
Yukon sweetclover	6.3

Yukon treatments, however, had fresh and dry weight values, which were significantly higher than in the Norgold treatments (Table 2.2).

* See Chapter 4.

Table 2.2. Fresh and dry weights of total weed numbers for the three treatments.

Treatment	Fresh weight (grams)	Dry weight (grams)
Yukon sweetclover	34.7	4.60
Norgold sweetclover	31.6	4.10
Poplar shavings	31.0	4.00

Poplar shavings had a significant effect on lowering the fresh weight of wheat, and the dry weight of chenopodiaceae. This suggests the existence of a physical effect suppressing weed levels of certain species.

Rates of residue applications had significant effects on several of the dependant variables we measured; (number of wheat plants, number of weeds, number of chenopodiaceae, number of graminae, dry weight of polygonaceae). The highest rate of residue (6 t/ha) was significantly different than the lowest rate (1.5 t/ha) or in some cases the lowest two rates (1.5 and 3.0 t/ha) of residue. The exceptions were the dry weight of polygonaceae and graminae, where the highest residue rates yielded the highest dry weights (Table 2.3).

Table 2.3. Dry weight of graminae weeds.

Residue added (t/ha)	Dry weight (grams)
6.0	1.5
3.0	1.5
1.5	1.3

Method of placement significantly affected fresh weight of wheat, dry weight of wheat, number of weeds, dry weight of cruciferae, number of chenopodiaceae, dry weight of chenopodiaceae, number of graminae, dry weight of graminae, number of polygonaceae, dry weight of polygonacea, and the dry weight of weeds. Incorporation caused decreased plant populations and weights in these dependant parameters, with the exceptions of number of weeds, number of cruciferae, and dry weight of chenopodiaceae. In these parameters surface applications of residues provided the greatest control of the particular weed group.

The analysis of variance of the experiment treating it as a completely randomized design with 13 treatments (including the control) had the majority of measured dependant variables showing significant differences between treatments. However, very few trends or patterns seemed to be appearing.

The highest rate of Yukon sweetclover (surface and incorporated placements) tended to have lower weed populations in terms of plant numbers, total weeds, chenopodiaceae weeds, graminae weeds and cruciferae weeds. Only the dry weight of the chenopodiaceae was significantly lowered by the high rate of Yukon sweetclover. So although many of the weed <u>numbers</u> were lowered, few of their <u>dry weights</u> were lowered comparatively. This may indicate that as weed numbers decreased, competition decreased, allowing the weeds that did grow to become larger. The differences between treatments were not usually significant, but the trend seemed to suggest that Yukon (high coumarin variety) may be having an effect, which is allelopathic in nature. Wheat and certain weed families are being affected. Where significant differences were found to occur, it was not uncommon for the treatment with the highest mean to

be significantly different from the lowest mean treatment. Although in some cases the Yukon treatments appeared to be having a significant effect upon weed populations, in other cases it appears to be more of a physical factor rather than a chemical factor, which is reducing values. Weed control may be a result of adding high rates of any residue.

Conclusions

From this experiment there appears to be some evidence to support the theory that Yukon sweetclover, a variety high in coumarins, is having an allelopathic effect on certain weed groups, as well as winter wheat. However, the data does not strongly support this and none of the results of the pot experiment are conclusive. In many cases, as in the canola experiment, there appears to be a physical factor affecting plant populations, and their dry weights. There does not appear to be a great deal of correlation between plant numbers and their respective dry weights throughout this experiment. This may be in part due to experimental error, or to changes in competition levels.

In a few cases sweetclover seems to have a positive effect on weed growth (example: the dry weight of chenopodiaceae).

Although it was an objective of this experiment to simulate field conditions, major experimental flaws exist. In a normal farm field situation, a lag of approximately 50 days exists between the incorporation or desiccation of sweetclover residue, and the seeding of winter wheat. During this period decomposition of the residue would begin, resulting in possible allelochemical release into the soil. This might allow for great weed control.

Studies by Meyer in North Dakota noted the stimulatory effect of sweetclover residues on wheat. When wheat was seeded on land, which had grown sweetclover (subsequently incorporated) wheat yields were significantly higher. This is likely due to the release of nitrogen from the decomposing clover residue. The pot experiment failed to incorporate the lag period, which might have had a stimulatory effect on winter wheat, and an inhibitory effect on certain weeds. In the pot experiment sweetclover residue was used, which had been air dried, and may well have lost its coumarin, which has been shown to have inhibitory effects upon plant growth of certain species.

Winter wheat may also have played a role in releasing allelopathic root exudates. The exudates may affect weed numbers. Although we should be aware of this theory, there didn't appear to be strong evidence to support this, when examining the data. The experiment did have a control treatment, which had no residues added. This allowed us to examine the effect the winter wheat may have had on weed populations. The effect did not appear to be significant.

This experiment like the one done previously with canola straw/chaff is affected by a great many variable factors. There may be several time related factors, which are having an effect on weeds and the wheat. We have already mentioned the lag period, but also there may be the different time frames involved with growth of wheat versus weeds, and the stages of development of one versus the other. These time factors may very well affect the results of the experiment, but it becomes difficult to quantify them.

CHAPTER 3

EFFECT OF CANOLA STRAW AND CHAFF ON WHEAT PRODUCTION AND WEED SUPPRESSION

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Description of Activity

A field test at the Kernen Crop Research Farm was laid out in canola stubble. Three rates of application of canola straw and three rates of canola chaff were spread in the standing stubble. Two additional canola residue treatments were straw and chaff dropped from combine without spreading, and straw and chaff similarly left in a windrow and burned. Winter wheat was sown in part of the treated area in September, 1986 and spring wheat was sown in the remainder of the treated area in the spring of 1987. Stand counts were taken in fall and spring and grain yields were taken at maturity.

Objectives

To test in field trials for the presence of allelopathic substances in canola.

Materials and Methods

The levels of straw and chaff spread in the canola stubble were at 0, the amount produced by the harvested crop in the experimental area, and double the harvested amount, i.e. 0, 2140 and 4280 kg/ha of straw, and 0, 1920 and 3840 kg/ha of chaff. The nine treatment combinations

were arranged in a 3 x 3 Factorial in a Randomized Complete Block with six replications. The two windrowed treatments were included in each replication to assess the effects of a very heavy rate of residue concentrated in a narrow strip. Plot size was 5 by 16 m.

Milestones

Winter wheat yields were affected by canola chaff, but not significantly by straw. The interaction between chaff and straw was not significant. Mean effect of the nine combinations are shown in Table 3.1 below.

Table 3.1. Effect of canola straw and chaff residues on yield of Norstar winter wheat, kg/ha (1987, Saskatoon).

Level of chaff kg/ha	Level of straw (kg/ha)			
	0	2140	4280	Mean
0	910	1050	1230	1060
1920	790	1210	1140	1040
3840	1280	1330	1420	1340
Mean	990	1190	1260	1150

In Katepwa spring wheat, grain yields were increased by both straw and chaff of canola, even when applied at double rates. Yields are shown in Table 3.2.

Table 3.2. Effect of canola straw and chaff residues on yield of Katepwa spring wheat, kg/ha (1987, Saskatoon).

Level of chaff kg/ha	Level of straw (kg/ha)			
	0	2140	4280	Mean
0	1080	1460	1540	1360
1920	1200	1420	1810	1480
3840	1480	1700	2050	1740
Mean	1250	1530	1800	1530

There were few weeds growing in either the winter or spring wheat, but substantial number of volunteer canola plants. Since the 1987 experiments indicated a beneficial effect of canola residues on wheat yields this experiment was established again in September 1987, in another location on the Kernen Crop Research Farm.

Date of Completion

December, 1989.

Note: Crop failure in 1988 caused us to cancel this experiment. It was replaced by field study of the effects of killed young canola plants (Chapter 6) which effect was felt to better exploit allelopathic effects to control weeds.

CHAPTER 4

GROWTH ROOM STUDIES ON THE EFFECTS OF CANOLA CROP RESIDUES ON WEEDS

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Experiment

The study was conducted to measure the effect of placement and amount of canola residues on weed populations and winter wheat emergence and early growth. Effects tested were two rates of residue (straw and chaff) and surface or soil incorporation of the residue or poplar shavings control.

Materials and Methods

Sixty-five, 17.5 cm plastic pots were lined with plastic bags and filled with 1400 grams of soil. To 400 grams of soil half of the residue treatment was added, and mixed thoroughly. For the non-residue treatments, and treatments receiving only surface residues, 400 grams of soil was used. This was placed on top of the 1400 grams of soil in each pot and lightly compressed. Twelve winter wheat seeds were placed on the surface towards the centre of the pot, and twelve de-awned wild oat plants were placed around the outer edge of the pots. An additional 400 grams of soil had 3 grams of mixed weed seeds added, and the remaining half of the residue treatment, thoroughly mixed throughout and placed on top of each pot. Soil and weed seeds were used for the no residue and surface residue treatments, and canola straw and chaff or poplar shavings were placed on the surface for these treatments. Five replicates of each of the following treatment combinations were prepared.

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[2] Present address: Safer Chemicals, Victoria, B.C.

Residue X	Rates X	Placement
Either Canola straw and chaff, or Poplar shavings, or No residues	Either 2 t/ha (4.8 g/pot), or 4 t/ha (9.5 g/pot)	Either surface only, or incorporated only

Each pot was then watered to 80% of field capacity by weight, and maintained by watering every second day. The experiment was started on July 22, 1987 to be harvested on either the week of August 17 or August 24. Nutrient solution (20-20-20) was added July 29 and August 12. Harvesting of the pots was done on August 18 (Replicates 1, 2 and 3) and August 19 (Replicates 4 and 5). At this time plant number counts, and fresh weights were taken. Dry weights were taken at a later date when drying was completed. Drying was done at a temperature of 30-35°C.

Analysis

The experiment was analyzed in two ways:

1) an analysis of variance considering the experiment as a completely randomized design with 13 treatments. The control is considered to be the thirteenth treatment.
2) an analysis of variance considering the study as a factorial experiment (control is not included).

e.g. Treatment 1 three rates of residue two placements

Treatment 2 three rates of residue two placements

Student-Newman-Keuls tests as well as a calculation of means were also done for each method of analysis. The Student-Newman-Keuls (SNK)

test is done to determine if significant differences exists between means.

The analysis of variance of the experiment (treating it as 13 treatments in a completely randomized design) showed that the number of wheat plants, fresh weight of wheat, and dry weight of wheat were not significantly different among the 13 treatments. An expected relationship existed between wheat numbers, fresh weight and dry weight.

Total weed numbers, fresh weight of weeds, and dry weight of weeds were significantly affected among treatments. The trend for lower weed numbers, fresh weights, and dry weights at higher residue levels (poplar and canola straw/chaff) was illustrated quite clearly by the SNK analysis. Treatments with the higher residue levels (4 and 8 t/ha) consistently had lower weed numbers, fresh weights and dry weights. The poplar residues at the high levels had a greater effect than did the canola residue in reducing weed numbers.

The number of monocot weeds (wild oats and foxtail) and the dry weight of monocot weeds showed no significant differences among treatments. Unexpectedly, the fresh weight of monocot weeds showed some significance in the difference among treatments.

The number of dicot weeds, the fresh weight of dicot weeds, and the dry weight of dicot weeds had differences, which were highly significant among treatments. The high residue levels again showed significant differences from the low residue treatments and the control. The dicot weeds we counted in the experiment were: buckwheat, stinkweed, lamb's quarters, Russian thistle, and Brassica sp. weeds. High residue rates of poplar and canola both seemed to have this effect on reducing numbers of plants and fresh and dry weights. Treatment 7, which is a treatment

of poplar shavings incorporated at the lowest rate was an exception to the pattern throughout the experiment, especially for the dicots. It had the best or near best control of the dicot weeds. Its results may be somewhat misleading, since it definitely does not follow the pattern we had come to expect in this experiment.

Conclusions

Differences exist between treatments for the dependant variable parameters, which we measured. However, these differences appear to be due to a physical effect of high residue levels rather than a chemical effect. The lowest residue rates were not significantly different from the control for any of the variables we measured. Table 4.1 shows the effect that high residue levels had on total weed numbers. Several other parameters reacted in a similar way to high residue rates.

Table 4.1. Total number of weeds for the thirteen treatments.

Treatment	Residue level	Mean number of weeds
10	2 t/ha	80
4	2 t/ha	72
2	4 t/ha	67
5	4 t/ha	62
13	0 (control)	62
8	4 t/ha	57
11	4 t/ha	57
7	2 t/ha	53
3	8 t/ha	48
1	2 t/ha	47
6	8 t/ha	44
12	8 t/ha	38
9	8 t/ha	38

The factorial analysis of this experiment (control excluded) helped to support many of the findings of the other analysis method of the experiment where we treated it as having 13 treatments.

The number of wheat plants, and the dry weight of wheat was not affected by rate, treatment, place or any interaction of the three. This corroborates that no differences were found using the analysis of variance on the 13 treatments. The number of weeds were affected by rate, place, and an interaction of the two, but not by treatment. Treatment refers to canola straw/chaff residue or poplar shavings. Again this seems to indicate that weeds were decreased by the higher rates, and by incorporation, but not by any chemical residues given off or released by the canola residues. Fresh and dry weights of weeds were affected in a similar manner to number of weeds. However, treatments had an effect, with poplar shavings (chemically inert) giving greater weed control. This suggests a physical rather than chemical effect (Table 4.2).

Table 4.2. Fresh and dry weights of weeds.

Fresh weight of weeds (g)	Dry weight of weeds (g)	Treatment
16.2	2.0	canola straw/chaff
13.2	1.6	poplar shavings

Fresh weight of dicots was affected by treatment, rate, place, and a treatment by place interaction. Poplar treatments, incorporation, and high residue rates all minimized dicot fresh weights. The number of

dicots, and their dry weight were affected in a similar manner; however treatments did not have a significant effect.

The number of monocot weeds was significantly affected by treatments. The poplar treatments had a significantly lower number of monocots than did the canola treatments. Monocot fresh weights were affected by treatment and place, while dry weights were affected by place.

Although the dependant variables analyzed were affected by different factors (independent variables), both the factorial and randomized analysis showed some very definite tendencies. The residue added (canola straw/chaff vs poplar shavings) affected a few of the dependant variables. Number of weeds was affected. Where there were significant effects, in all cases the poplar shavings residue gave the greatest weed reduction. Table 4.2 illustrates this. Wheat numbers and weights were not significantly affected. Since poplar shavings are considered to be chemically inert (previous tests done) we can infer that the cause of the reduction in the dependant variables, such as weed numbers; is due to physical factors such as shading and mulching. Decreases over the control that canola straw caused, can also be assumed to be largely caused by physical factors. Residue effects appear to be very small, if existent at all.

Where significant weed suppression was shown to occur, the higher rates caused greater suppression. Again this suggests that the cause of weed reduction was physical rather than allelochemical. High rates caused physical problems such as over mulching or shading (Table 4.3).

Table 4.3. The effect of residue rates on weed numbers and weed dry weights.

Rate of Residue	Number of weeds	Dry weight of weeds (grams)
2 t/ha	1.9	64.1
4 t/ha	1.9	60.7
8 t/ha	1.6	41.7

Treatments utilizing incorporation showed greater weed suppression on average than did treatments using surface residue applications. This seems to point to the mulching effect as having a greater effect than shading in reducing certain dependant variable values. Shading would seem to be having less of an impact. Table 4.4 shows how number of dicots and dry weights of dicots are affected by the method of application.

Table 4.4. The effect of residue placement on number of dicots and their dry weight.

Placement of residue	Number of dicots	Dry weight of dicots
surface applied	46.2	1.1
incorporated	38.3	0.7

There appears to be little evidence in this particular pot experiment to support theories relating to the release of allelopathic chemicals, from canola straw/chaff residues, which would subsequently have an effect on weed population control. However, possible alterations in the experiments might have produced different more promising results.

Dry canola straw/chaff was used in the experiment. Volatization of allelopathic chemicals has been documented, therefore it is possible that the dried canola straw/chaff no longer contained its allelopathic compounds. In a field situation the canola residue lies on the surface and decomposes gradually. Allelopathic compounds have the ability to permeate and leach into the soil, where they are more stable and can be stored there for some time. The design of this experiment failed to incorporate that fact. As well, the allelopathic compounds may be added to the soil as a result of root exudation. The pot experiment failed to incorporate that possibility as well. Finally, winter wheat seedlings may be releasing root exudates, which affect weed populations, and possibly even winter wheat populations. Therefore, it becomes clear that a great number of factors must be considered in the evaluation and design of an experiment such as this one.

CHAPTER 5

EFFECT OF YOUNG CANOLA AND MUSTARD PLANT RESIDUES ON GERMINATION AND EARLY GROWTH OF KOCHIA AND GREEN FOXTAIL WEEDS

A. Mair and E. Coxworth

5.1 Initial Studies of the Effect of Canola and Mustard Residues on Kochia

Introduction

Plant residues from the genus Brassica have been reported to reduce growth and yield of some plants (Rice, 1984). Some of the observed effect is often attributed to phytotoxins either leached from the residue or produced during microbial decay (Campbell, 1959; Harper and Lynch, 1982; Leather, 1983 and McCalla and Norstadt, 1984). This method of use may also result in the decline of phytotoxicity as residues decompose (Guenzi, McCalla and Norstadt, 1967).

Vera (1982) and Vera et al. (1987) found that canola (B. napus) and mustard (B. juncea) reduced the growth and yield of various following crops. The effect was much stronger for young plants than for crop residues.

Allelopathy is the term used to describe this growth regulating effect from natural chemicals released by plants (Rice, 1984). Most references have been to problems of a particular crop residue inhibiting the growth of a subsequent crop. Only recently have scientists started to develop weed control systems exploiting this phenomenon. Forcella (1986) developed a method using winter hardy canola as a weed suppressing fall-spring cover crop for a continuous, zero-tillage corn production system. The canola was planted after corn harvest in the fall. Canola started regrowth in the spring and was killed by one

application of 2,4-D in late spring, just before corn was planted. The corn grew through the dead canola residue and gave a yield comparable to a conventional zero-till corn production system without the canola cover crop. Weed control with the canola cover crop was nearly as good as in the conventional zero-till system, and overall weed control costs were only half the usual method.

The effect of Brassica crop residues on a subsequent crop appears due in part to the release of phytotoxic chemicals. These chemicals may be extracted directly from the residues, or may results from microbial activity during decomposition (Lynch and Cannell, 1980). Indole glucosinolates occur in substantial amounts in the vegetative parts of Brassica and are in highest concentration in young actively growing tissue (Robbellen and Thies, 1980). Glucobrassicin, an indole glucosinolate, at 0.001 M, and a degradation product, 3-indolylacetonitrile, at 0.00001 M, were observed to inhibit the growth of wheat and clover (Kutacek, 1964).

Allyl isothiocyanate is one of the enzymatic breakdown products of the glucosinolate present in B. juncea. It is closely related to methylisothiocyanate, which has been shown to be a very effective "seedicide", i.e., a chemical destroyer of the viability of ungerminated weed seeds (Teasdale and Taylorson, 1985).

Studies of the allelopathic potential of several crops indicated that rape inhibited the growth of several weeds and inhibited the germination of wild mustard (Leather and Hurtt, 1982). Various Brassica species differed considerably in their allelopathic ability (Mason-Sedun et al., 1986).

Kochia (Kochia scoparia L. Schrad) is a very common weed on cultivated saline soil, but is also being developed into a high yielding forage crop for saline soils (Green et al., 1986). It would be very useful to have a cover crop that would suppress growth of kochia where it was not wanted, as part of an overall system of controlled use of this plant as a forage.

This study was conducted to determine if the roots and top growth of young B. napus and B. juncea may be phytotoxic to kochia germination and/or growth and to compare the results with control plants.

Materials and Methods

Experiment 1. Canola effects on kochia

Canola seeds were planted in a sand-soil mixture on November 30, 1987 and grown for two weeks at room temperature (~20°C). The roots were left in the soil after harvesting and the tops were dried and retained. During the time interval of 23 days, between harvesting the canola and planting the kochia, the soil was kept moist.

On January 7, 1988, four kochia seeds were planted in each of six, 16 cm^2 pots containing the canola roots. The dried canola residue was evenly spread over the surface of the soil.

Another six pots were planted with four kochia seeds per pot and poplar mulch was spread evenly over the soil surface (for shading effect). A third set of six pots was also planted with four kochia seeds per pot with no residue on the soil surface.

All kochia seeds used were from one kochia plant harvested in Saskatoon, Saskatchewan in October, 1986. These seeds had 98% germination.

The number of kochia seedlings per pot was counted at one week. The plants were thinned to two plants per pot, then grown for another two weeks at 25°C. They were watered daily to 80% field capacity. Measurements of plant height were taken on January 20 and 27, 1988. After harvest, on January 28, wet weights were taken per pot and the plants were oven dried overnight at 60°C.

Experiment 2. Canola and mustard effects on kochia compared

Brassica napus (canola) (c.v. Westar) and Brassica juncea (mustard) (c.v. Domo) seeds were planted March 3, 1988 in a sand-soil mixture and grown for four weeks at ~20°C and watered daily to 80% field capacity. Eight seeds were planted one cm deep. After two weeks, the young plants were thinned to four plants per pot. The canola plants had grown to produce a closed canopy over the 6 inch diameter pots and the mustard plant had produced flowers just before harvest (26 days from seeding). All the plants were cut at the soil surface, weighed, then cut into ~5 cm pieces. The same pots, with the Brassica roots, were planted with ten kochia seeds and the cut plants were put back on the surface of the same pot from where they had grown. Control pots were set up at this time. One set of five controls had poplar shavings spread on the soil surface equal to an average amount of calculated dry Brassica shoots (estimated at 6.3 g per pot) for shading effect. Another set of five controls were also planted with ten kochia seeds, but with no residue on the surface. After two weeks the kochia plants were thinned to five plants per pot, then grown for another two weeks. Plant heights were taken once a week after they had been thinned.

At harvest, the kochia plants were cut at the soil surface, weighed, dried in a forced air drying oven at 30°C, then weighed again.

Results and Discussion

Experiment 1. Effect of canola on kochia

The oven dry weight of the canola residue, which was spread over the soil surface, was 0.37 g/pot. An equal amount of poplar shavings was used on one set of the controls.

The canola residue significantly reduced kochia germination and had a significant effect on the yield, after 21 days growth, of the plants which had germinated (Table 5.1).

Table 5.1. The effect of canola residue on kochia growth.

Treatment	Height (cm) Jan. 27/88	Yield (g/pot)	Germination (%)
Control 1[1]	3.3	0.082	100
Control 2[2]	2.6	0.082	100
Canola residue	2.6	0.058	29
Significance of treatment effect	NS	**	**

1 control with poplar
2 control with no residue
** highly significant (P>0.05)

Experiment 2. Effects of canola and mustard on kochia compared

When the Brassica plants were cut and spread on the soil surface to test the phytotoxic effect, a strong smell was detected. This may

indicate that some of the toxic material was volatilizing off the plants into the air, reducing the phytotoxic effect. Incorporating the Brassica residue into the top 5 cm of soil in future experiments may limit the loss of these vapors. It is known that idolylacetonitrile (from B. napus) and allylisothiocyanate (from B. juncea) are very volatile (I. McGregor, personal communication). In a closed container, volatiles released from crushed Cruciferae plants were very phytotoxic to small seeds (Oleszek, 1987).

Even with the Brassica plants spread loosely on the soil surface in the present study there was a significant phytotoxic effect on the kochia plants. The lower yields and % germination show how the kochia plants are effected by the Brassica species tested (Table 5.2).

Table 5.2. The effect of B. napus and B. juncea on kochia germination and growth.

Treatment	Germination (%)	Height at harvest (cm)	Air dry weight (g/pot)	Air dry weight (g/plant)
B. napus	22[a]	13.1[b]	1.1[a]	0.5[b]
B. juncea	64[b]	9.0[a]	1.3[a]	0.3[a]
Poplar	92[c]	15.3[c]	4.0[c]	0.8[c]
No residue	88[c]	15.5[c]	3.1[b]	0.6[bc]
Significance of effect	***	***	***	***

Means within a column with the same superscript are not significantly different according to Duncan's Multiple Range Test (P<0.001).

It is noteworthy that the effect of B. napus and B. juncea were different. B. napus inhibited germination more than B. juncea, whereas

B. juncea had a more negative effect on the growth of plants. Both soil incorporation, and testing of mixed populations of the two Brassica species should be evaluated next. Other weed species should also be tried. Forcella (1986) reported that canola green manure residue was very toxic to green foxtail.

One interesting possibility would be to test these Brassicas as green manure substitutes for fallow, i.e., chem fallows with most of the 'chem' coming from the green manure cover crop. The Brassica species could be killed very early in the season to allow capture of soil moisture of the June rainfall.

5.2 Determining the Phytotoxic Effects of Canola and Mustard, Killed with 2,4-D, on Kochia and Green Foxtail Growth.

Introduction

This growth room experiment was designed to simulate the procedures used in the field experiments to compare results in a more controlled environment and to compare the effects of canola with those of mustard.

Mustard and canola have been found to reduce the growth and yield of various following crops (Vera, 1981 and Vera et al., 1987).

The effects measured in this experiment were shading, chemical allelopathy, and competition, and the objectives were to test how these effected kochia germination, growth and yield.

Experiment 1. Effects on Kochia

Materials and Methods

A mixture of five parts soil, one part sand, and one part vermiculite was prepared at 75% field capacity, in 171 cm^2 surface area planting pots. Eight mustard seeds (Brassica nigra, var. Domo) and eight canola seeds (Brassica napus, var. Westar) were planted 1 cm deep in separate pots. When the first pair of true leaves emerged, the plants were thinned to four plants per pot. After seven days, ten kochia seeds (native to Saskatchewan) were planted amongst the canola plants and ten kochia seeds were planted amongst the mustard plants. Another ten pots with kochia seeds only, were set up for controls and shading affect. The kochia seeds were thinned to five plants per pot after the first true leaves appeared. All tests were replicated five times. All pots were watered daily, kept in a growth room with 18 hrs light, at 21°C, fertilized and measured weekly. Light levels at 20 cm from the lights were approximately 200 uE/cm^2.

When the canola and mustard plants had grown for four weeks, low volatile ester 2,4-D was prepared by diluting 11.2 ul in 50 ml distilled water. A volume of 5 ml per pot was applied by brushing the chemical onto the leaves, stems and buds of the canola or mustard only. This method simulated wick applying 2,4-D in the field. The 2,4-D was allowed to dry on the plants in a fumehood, then the plants were returned to the growth room.

The plants with 2,4-D applied were showered with water (beginning at least 24 hrs after 2,4-D treatment) from above to simulate rain. All treatments were watered at one to two day intervals to the weight measuring initially for 75% field capacity.

At the time 2,4-D was added to one group of canola plants and one group of mustard plants with the kochia interplanted, another group of each of canola and mustard plants were cut at the soil surface, top growth removed, and the kochia plants were left to grow in the canola and mustard roots. Shading was provided by plastic leaves on plastic stems to one group of kochia control plants at approximately the same degree of shading provided by live canola or mustard plants. Another group of kochia plants (no mustard or canola) were left to grow undisturbed. At weekly intervals during growth of the plants, the plants were watered with a dilute fertilizer (20-20-20) solution.

Two weeks after 2,4-D was applied, the canola and mustard plants were very stressed, having twisted stems, dead or dying leaves, but the plants were not dead so a second application of 2,4-D was necessary. Four days later the plants were almost completely dead and all plants were then harvested at thirty-eight days old. Plants heights, fresh and air dry weights were measured and statistically analysed.

Results

The canola and mustard plants that were killed with 2,4-D had an effect on the kochia plants that were growing in the same pot. The initial effect of shading and/or natural chemicals released from the canola and mustard, before adding the herbicide, resulted in stunted plants. The subsequent effect of the 2,4-D or of phytochemicals from the killed cover crops leaching off the plants onto the kochia plants below may have been the cause for the kochia plants to wilt, curl up, stop growing or die.

Plastic shading that was applied after the kochia plants were well established (nineteen days old) had only a small effect on growth compared to the control plants (Table 5.3).

Kochia plants that were grown in the same pots as the canola and mustard plants were very small. Once one group of the canola and mustard plants were cut down, the kochia plants began to grow, but were still significantly affected (see Table 5.3). This effect suggested that toxins release from the roots of the cover crops might be having a growth suppressing effect even though competition and shading effects had been removed.

Table 5.3. The effect of canola and mustard treated with 2,4-D, or shading, on kochia growth compared to controls.

Treatment	Mean Height at Harvest (cm)	Whole Plant Fresh Wt. (g/pot)	Whole Plant Air Dry Wt. (g/pot)
Canola with 2,4-D	4.5[a]	1.0[a]	0.2[a]
Mustard with 2,4-D	2.7[a]	0.4[a]	0.1[a]
Canola roots only	10.8[b]	8.2[b]	0.8[b]
Mustard roots only	9.4[b]	8.2[b]	0.7[b]
Shading Effect	23.7[c]	42.7[c]	5.3[c]
No residue	23.3[c]	46.9[d]	6.4[d]
Significance of effect	**	**	**

** highly significant ($p>0.01$)

Means within a column with the same superscript are not significantly different according to Duncan's Multiple Range Test ($p>0.05$).

Conclusions

The effect of the mustard or canola on kochia growth and yield was highly significant. Both Cruciferae species were equally effective in reducing kochia growth. Shading had a small, but significant, inhibitory effect.

Experiment 2. Effects on Kochia and Green Foxtail

Materials and Methods

A mixture of five parts soil, one part sand, and one part vermiculite was prepared at 75% field capacity in 171 cm^2 surface area planting pots. Eight mustard seeds and eight canola seeds were planted in separate pots, 1 cm deep. When the first pair of true leaves emerged, the plants were thinned to four plants per pot. After seven days, ten kochia seeds (native to Saskatchewan) were planted amongst the canola plants and ten kochia seeds were planted amongst the mustard plants. Another ten pots, with kochia seeds only, were set up for controls and shading affects. The kochia seeds were thinned to five plants per pot after the first true leaves appeared. All tests were replicated five times. All pots were watered daily, kept in a growth room with 18 hrs. light, at 21°C, fertilized (20-20-20), and measured weekly. This entire procedure was repeated with green foxtail seeds in place of kochia seeds for a total of sixty pots.

When the canola and mustard plants had grown for four weeks, low volatile ester 2,4-D was prepared by diluting 11.2 ul in 50 ml of 1% Triton X (as a surfactant). A volume of 5 ml per pot was applied by brushing the chemical onto the leaves, stems and buds of the canola or mustard plants. This method simulated wick applying 2,4-D in the field.

The 2,4-D was allowed to dry on the plants in a fumehood, then the plants were returned to the growth room.

The plants with 2,4-D applied were showered with water from above to simulate rain and (perhaps) leach chemicals from the treated canola and mustard plants onto the healthy kochia or foxtail plants below.

At the time 2,4-D was added to one group of canola plants and one group of mustard plants, with the kochia or foxtail interplanted, the other groups of canola and mustard plants were cut at the soil surface, and the kochia and foxtail plants were left to grow in the soil containing the canola and mustard roots. Another group of kochia and foxtail plants only had shading applied above them. The remaining group of kochia and foxtail plants were left to grow undisturbed.

One week after 2,4-D was applied, the canola and mustard plants were very stressed, having twisted stems, dead or dying leaves. The surfactant, used to keep the liquid 2,4-D on the leaves, proved to be quite helpful and the canola and mustard plants were dying more rapidly than in experiment 1. At this time a second application of 2,4-D was brushed on to the canola and mustard leaves.

During the sixth week, all plants were harvested. Fresh and air dry weights were measured. Dry matter yields were statistically analysed.

Results

The canola and mustard plants that were killed with 2,4-D had a highly significant effect on the kochia plants that were growing in the same pot (see Table 5.4). The initial effect of shading and/or natural chemicals released from the canola and mustard, before adding the

herbicide, resulted in stunted, immature plants. The effect of the 2,4-D leaching off the plants onto the kochia plants below, may have been the cause for the kochia plants to wilt, curl up, stop growing or die.

Table 5.4. Effect of canola and mustard plants, treated with herbicides, on kochia growth and yield compared to the control and to shading effects.

Treatment	Mean Height at Harvest (cm)	Mean Yield (g/pot) (air dried)	Mean Yield (g/m^2)	Yield as a percent of control (%)
Canola + 2,4-D	4.7[a]	0.1[a]	7.2[a]	2.3
Mustard + 2,4-D	4.5[a]	0.2[a]	10.1[a]	3.2
Canola roots	11.1[b]	0.9[b]	53.9[b]	17.1
Mustard roots	11.0[b]	1.0[b]	58.2[b]	18.1
Shading	23.3[c]	4.2[c]	243.1[c]	77.1
No residue	23.2[c]	5.4[d]	315.3[d]	100
Significance of effect	**	**	**	

** highly significant (p/0.01)

Means with a column with the same superscript are not significant different according to Duncan's Multiple Range Test (p>0.05).

The foxtail plants were not as visually affected by the herbicides as the kochia, but statistically there was a high significance of effect (see Table 5.5). Natural chemical and physical affects could be responsible for the growth reduction in foxtail. The growth suppressed foxtail had brown spotting on the leaves (possibly the fungal disease brown spot) which could be a secondary allelopathic affect since the 2,4-D does not affect grasses.

Table 5.5. Effect of canola and mustard plants, treated with herbicide, on foxtail growth and yield compared to the control and to shading effects.

Treatment	Mean Height at Harvest (cm)	Mean Yield (g/pot) (air dried)	Mean Yield (g/m^2)	Yield as a percent of control (%)
Canola + 2,4-D	13.9[a]	0.2[a]	12.7[a]	6.0
Mustard + 2,4-D	16.6[a]	0.3[a]	19.0[a]	8.9
Canola roots	23.6[b]	1.1[b]	62.5[b]	29.3
Mustard roots	23.7[b]	1.2[b]	72.4[b]	34.0
Shading	38.6[c]	3.6[c]	213.9[c]	100
No residue	38.0[c]	3.6[c]	213.1[c]	100
Significant of effect	**	**	**	

** highly significant ($p>0.01$)

Means within a column with the same superscript are not significantly different according to Duncan's Multiple Range Test ($p>0.05$).

Conclusions

It was clear from this study, that the Brassica species napus and juncea, planted as cover crops, which are then killed with an application of herbicide, could dramatically decrease kochia and green foxtail weed yield.

Experiment 3. Effects on Kochia and Green Foxtail

The following experiment was conducted to study the physical and chemical (natural and induced) effect of Brassica napus (canola) and Brassica juncea (mustard) on interplanted kochia and foxtail growth and yield, and compare results with field experiments.

Materials and Methods

A moisture of five parts soil, one part sand, and one part vermiculite was prepared at 75% field capacity in 171 cm^2, surface area, planting pots. Eight mustard seeds and eight canola seeds were planted in separate pots, 1 cm deep. When the first pair of true leaves emerged, the plants were thinned to four plants per pot. After seven days, ten kochia seeds (native to Saskatchewan) were planted amongst the canola plants and ten kochia seeds were planted amongst the mustard plants. Another ten pots with kochia seeds only, were set up for controls and shading affect. The kochia seeds were thinned to five plants per pot after the first true leaves appeared. All tests were replicated five times. All pots were watered daily, kept in a growth room with 18 hrs. light, at 21°C, and fertilized and measured weekly. This entire procedure was repeated with green foxtail seeds in place of kochia seeds for a total of sixty pots.

When the canola and mustard plants had grown for four weeks, low volatile ester 2,4-D was prepared by diluting 11.2 ul in 50 ml distilled water. A volume of 5 ml per pot was applied by brushing the chemical onto the leaves, stems and buds. This method simulated wick applying 2,4-D in the field. The 2,4-D was allowed to dry on the plants in a fumehood, then the plants were returned to the gorwthroom.

The plants with 2,4-D applied were showered with water from above to simulate rain and perhaps leach chemicals from the treated canola and mustard plants onto the healthy kochia or foxtail plants below.

At the time 2,4-D was added to one group of canola plants and one group of mustard plants, with the kochia or foxtail interplanted the other groups of each of canola and mustard plants were cut at the soil

surface and the kochia and foxtail plants were left to grow in the canola and mustard roots. Another group of kochia and foxtail plants had shading applied above them. The remaining group of kochia and foxtail plants were left to grow undisturbed.

One weeks after 2,4-D was applied, the canola and mustard plants were very stressed, having twisted stems, dead or dying leaves. The second application of 2,4-D was then added.

All plants were harvested at week six. The kochia were in flower stage and the foxtail had heads. Wet and air dry weight were recorded and yields were statistically analysed.

Results

The results were similar (Table 5.6) to those obtained in the previous experiment (see Tables 5.4 and 5.5).

Table 5.6. Effect of canola and mustard plants, treated with herbicide, on kochia or foxtail yield compared to control and shading effects.

Treatment	Mean Yield (g/m^2) Kochia Experiment	Mean Yield (g/m^2) Foxtail Experiment
Canola + 2,4-D	20.2^{2}	22.4^{ab}
Mustard + 2,4-D	10.4^{a}	14.9^{a}
Canola roots	98.8^{b}	108.9^{c}
Mustard roots	75.4^{b}	68.1^{bc}
Shading	234.5^{c}	177.8^{d}
No residue	431.5^{d}	221.5^{d}
Significance of effect	**	**

** highly significant ($p>0.01$)

Means within a column with the same superscript are not significantly different according to Duncan's Multiple Range Test ($p>0.05$).

Conclusions

In support of other experiments, the effect of the killed canola and mustard cover crops on kochia and foxtail yield was highly significant.

5.3 Experiments on Determining the Allelopathic Effect of Volatiles Released from Young Canola or Mustard Plant on Kochia and Green Foxtail Growth.

Introduction

Alelopathic plants release natural chemicals which may effect the germination and/or growth of other plants. Some of the phytotoxic effects of crop residues on succeeding plants have been attributed to phytotoxins leaching from the residues together with toxins produced during microbial delay (Bell and Muller, 1985). Oleszek (1987) suggested that degradation products of glucosinolates occurring in cruciferous plants cause an allelopathic action. Volatiles released may include isothiocyanates, nitriles and thiocyanates (Oleszek, 1987), and other compounds regarded as allelochemicals (Putnam, 1983, Wolf et al., 1984).

Another factor is the water soluble phytotoxins from some Brassica residues. They may contribute to the overall phytotoxicity of residues (Mason-Sedun, Jessop and Lovell, 1986).

In this experiment, the reduction of germination and/or growth caused by the allelopathic action of Brassica napus (Westar canola) and Brassica juncea (Domo mustard) volatiles was studied.

Materials and Methods

Mustard and canola plants were grown under growth room conditions for 4 weeks. Fresh green leaves from these plants were used for the experiment.

Germination tests were performed on 1986 Kochia scoparia L. Shrad seeds native to Saskatoon, Saskatchewan and on 1987 green foxtail (Setaria viridis) seeds. The germination chambers used were slightly modified from those of Muller et al., (1964). The chambers were 16 oz preserving jars with Whatman filter paper laid on the bottom of each jar. The filter paper was dampened with 3 ml distilled water and thirty seeds were distributed evenly on the paper. A plastic stand supporting a watchglass was placed in the middle of the chamber. Pulverised plant material was placed on the watchglass, and the jars were quickly sealed.

The plant material was prepared in the following way. One gram of green leaves were cut from the plant, immediately cut into pieces, and thoroughly pulverised in a mortar and pestle for 30 seconds. The sample was transferred onto the watchglass as quickly as possible , and the chamber was completely sealed to avoid loss of any volatile substances. The chamber were then left at room temperature (21°C for 72-94 hours. Germination counts were conducted every 24 hours and the whole seedling plant fresh weight was measured at the end of the experiment. All tests were replicated 5 times.

Results

Both kochia and green foxtail seeds showed very little sign of being effected by the canola volatiles. However, in both cases there was an obvious effect on both kochia and green foxtail by the mustard volatiles (Table 5.7 and Table 5.8).

Table 5.7. The effect of crushed canola and mustard leaves on kochia germination and growth in a sealed container.

Treatment	% Germination				Whole Plant	
	24 hrs	48 hrs	72 hrs	% Control	Fresh Wt.(g)	% Control
Control	95[b]	96[b]	97[b]	100[b]	0.26[b]	100[b]
Canola	93[b]	94[b]	95[b]	98[b]	0.23[b]	88[b]
Mustard	7[a]	29[a]	40[a]	41[a]	0.04[a]	15[a]
Significance of phytotoxic effect	**	**	**		**	

** highly significant (p>0.01)

Means within a column with the same superscript are not significantly different according to Duncan's Multiple Range Test (p.0.05).

Table 5.8. The effect of crushed canola and mustard leaves on green foxtail germination and growth in a sealed container.

Treatment	% Germination					Whole Plant	
	24 hrs	48 hrs	72 hrs	94 hrs	% Control	Fresh Wt.(g)	% Control
Control	0	33[b]	71[b]	79[b]	100[b]	0.16[b]	100[b]
Canola	0	32[b]	58[b]	76[b]	96[b]	0.14[b]	88[b]
Mustard	0	0[a]	11[a]	22[a]	28[a]	0.03[a]	19[a]
Significance of phytotoxic effect	NS	**	**	**	**	**	

** highly significant (p>0.01)

Means within a column with the same superscript are not significantly different according to Duncan's Multiple Range Test (p>0.05).

Foxtail seeds took longer to germinate, therefore, 24 hours was added to the germination time so the results would be more significant.

Repetition of these experiments (Tables 5.9 and 5.10) gave very similar results to the first series.

Table 5.9. Repeat of the effect of crushed canola and mustard leaves on kochia seeds in a sealed area.

Treatment	% Germination			Whole Plant	
	24 hrs	48 hrs	72 hrs	Fresh Wt. (g)	% Control
Control	90[b]	95	97	0.25[b]	100[b]
Canola	92[b]	95	98	0.25[b]	100[b]
Mustard	19[a]	71	91	0.10[a]	40[a]
Significance of volatile effect	**	*[1]	NS	**	

* significant (p>0.05)
** highly significant (p>0.01)
NS no significance

Means within a column with the same superscript are not significantly different according to Duncan's Multiple Range Test (p.0.05).

Table 5.10. Repeat of the effect of crushed canola and mustard leaves on green foxtail seeds in a sealed area.

Treatment	% Germination					Whole Plant	
	24 hrs	48 hrs	72 hrs	94 hrs	% Control	Fresh Wt.(g)	% Control
Control	0	23	58[b]	79[b]	100[b]	0.15[b]	100[b]
Canola	0	17	51[b]	77[b]	97[b]	0.15[b]	100[b]
Mustard	0	0	7[a]	22[a]	28[a]	0.03[a]	20[a]
Significance of volatile effect	NS	**[1]	**	**		**	

NS no significance
** highly significant (p>0.01)

Means within a column with the same superscript are not significantly different according to Duncan's Multiple Range Test (p>0.05).

[1] Although the F value showed high significance, there was no variance in the mustard germination making it difficult to compare means.

Discussion

Pulverised canola leaves did not significantly effect the germination of kochia or foxtail seeds compared to their controls. But the volatiles released from the mustard leaves retarded the germination and growth of the tested seeds significantly.

Results from other studies suggest that allylisothiocyanate in mustard is likely the effective volatile present, but indolylacetonitrile in canola, is either not volatile or not present in a significant amount. Although the nature of these volatiles is not completely known, the effect is very worthy of study. The results imply that there would be less herbicide drift, i.e., air borne volatile toxins, if canola was used as a killed cover crop rather than mustard.

Conclusions

The results of the growth room experiments were similar to the field experiments conducted with canola.

1. Canola and mustard had similar effects on kochia and green foxtail.

2. A volatile toxin was released by mustard but not by canola in tests conducted in sealed containers. Nonetheless, in growth room experiments both Cruciferae species had similar inhibitory effects on both kochia and green foxtail.

3. Even when the top growth of canola or mustard was removed growth of kochia and green foxtail was inhibited, although not nearly as much as when Cruciferae top growth was present.

4. Shading had a much smaller inhibitory effect on weed growth in the growth room than in the field. However, light levels in the growth room were much lower (~200 uE/cm^2) than in the field, and this may account for differences. Under some circumstances it has been shown that shading by one plant species can severely inhibit plant growth of an adjacent species (Aldrich, 1987).

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CHAPTER 6

FIELD EXPERIMENTS TO MEASURE THE EFFECT OF KILLED YOUNG CANOLA PLANTS AS COVER CROPS TO KILL OR SUPPRESS WEEDS: KOCHIA, GREEN FOXTAIL AND WILD OATS CONTROL.

K. Foster

Introduction

The high degree of weed control by killed young canola or mustard plants achieved in growth room studies (see Chapter 5) prompted us to test these effects in the field. Micro plots were established at the Kernen Farm of the University of Saskatchewan in 1988 and 1989. The results are described in this chapter.

Extremely hot and dry conditions prevailed in May and June of 1988 and the micro plots were not planted with canola until June 27th. The plots were irrigated (2.5 cm ha^{-1}) one day later. Tame oats (to mimic wild oats) was planted 9 days after the canola between the rows of canola. Kochia and green foxtail were planted 15 days after canola, again between the rows of emerging canola. This planting procedure was used to mimic the early planting of a cover crop followed by emergence of the weed species later.

Two control treatments were also included. In one treatment the individual weeds were planted by themselves into bare soil to measure weed yields with no restrictions due to cover crops. In the second control treatment poplar excelsior (shavings) was applied at a rate of 2 tonnes ha^{-1} after the individual weed species were planted. Poplar excelsior have been shown by previous investigators to be free of allelopathic effects so that the use of poplar tested the mulch effect only.

The two growing seasons (1988 and 1989) had different growing conditions. While both July's were slightly warmer (19.2°C and 20°C) than normal (18.4°C), July 1989 was much drier (27.8 mm) than normal (56.2 mm), while July 1988 was only 16% lower (at 47.0 mm) than normal (56.2 mm). August 1988 was cooler (16.8°C) than normal (17.2°C), but was much wetter (78.2 mm) than normal (35.1 mm). August 1989 was slightly warmer (18.5°C) than normal but was substantially wetter (58.5 mm) than normal. Thus the two growing seasons offered considerably different growing conditions. As the results indicate (q.v.) these differences were reflected in the degree of control achieved.

The effect of shading by the cover crop was tested in 1989. Aldrich (1987) has shown that shading by a taller plant species can substantially reduce the growth of a shorter species nearby and shaded. Boxes were made of lathe and plastic ribbon to reduce field light levels by about 50%, and were fitted over individual weed species plots to test this effect separate from competition for nutrients and moisture and allelopathic chemicals effects.

1988 Field Trials

Materials and Methods

Location: Kernen Crop Research Farm. L.S.D.: 8-37 4-W3-NW 1/4

Soil Association: Orthic Dark Brown Chernozemic - Sutherland clay loam

Experimental Design: The study was arranged as a randomized complete block design replicated 5 times. Each replicate contained 12 treatments consisting of 3 weed species, Green Foxtail (Setaria viridis), kochia (Kochia scoparia) and Tame oat (Avena sativa) each managed using 4 methods (Table 6.1). Individual plot size was 1 x 1 m with 2 m borders

between treatments. Following hand seeding of the Canola (Treatment #1 and 3) the crop was allowed to germinate and grow to the cotyledon leaf stage at which time all plots were seeded with one of the selected weed species. At this stage treatment #4 had poplar excelsior applied (2 tonnes ha^{-1}). Excelsior was held in place by nylon fish netting to prevent wind or applied water from disturbing the material. Plots were regularly rogued to preclude foreign plant species form interfering with specific treatment growth. The study was irrigated on June 24, 28, July 8, 21 and 28 to prevent moisture stress from interfering with the final results. Soil profile moisture was maintained at 50-75% of field capacity to a depth of approximately 10 cm.

Table 6.1. Allelopathy Treatments - 1988.

Treatment #	Management Procedures[1]
1	Canola plants (20 cm height) clipped at ground level with aerial residue left to decay on soil surface. Weed growth not disturbed.
2	No Canola plants present, only pure stand of either Green Foxtail, Kochia or Tame Oat.
3	Canola plants (20 cm height) killed by an application of 2,4-D (L.V. ester) @ 560 gai ha^{-1} using a "Wick" applicator. This method of application prevented any herbicide from contacting undergrowing plant material left in plot area.
4	Excelsior applied at a rate of 2 tonnes ha^{-1} immediately following weed seeding. No Canola plants present. Any growth consisted of pure stand of either Green Foxtail, Kochia or Tame Oat.

[1] Only designated species were allowed to grow in this study. All other plants were removed by hand roguing.

Canola Allelopathy Field Operations - 1988

Work Procedure	Date
Plot area watered to supply 2.5 cm ha^{-1} precipitation equivalent.	June 24
Canola seeded (12 kg ha^{-1} or 1.2 g/m^2)	June 27
Plot area watered to supply 2.5 cm ha^{-1} precipitation equivalent.	June 28
Tame Oat treatments seeded (22 seeds/m^2 - 92% germination).	July 5
Foreign plant material rogued from plot area.	July 8
Plot area watered to supply 1.0 cm ha^{-1} precipitation equivalent.	July 8
Kochia (25 seeds/m^2 - 80% germination) and Green Foxtail (250 seeds/m^2 - 90% germination) seeded.	July 11
Excelsior applied (2 tonnes ha^{-1}) to required treatments.	July 11
Foreign plant material rogued from plot area.	July 12
Plot area watered to supply 2.0 cm ha^{-1} precipitation equivalent.	July 21
Foreign plant material rogued from plot area.	July 27
Plot area watered to supply 2.0 cm ha^{-1} precipitation equivalent.	July 28
Weed Count (#/m^2) determined.	August 3
Herbicide application of 2,4-D (560 gai ha^{-1}) "wicked" on required Canola plots (Treatment #3).	August 4
Canola clipped at ground level (Treatment #1)	August 4
Herbicide application of 2,4-D (560 gai ha^{-1}) applied by "wick applicator" to all previously treated (August 4) plots (Treatment #3).	August 11
Weed Counts (#/m^2) determinations on treatments containing Tame Oat, Kochia and Green Foxtail.	August 18

Results and Discussion. 1988 Results

A. Green Foxtail (Setaria viridis) Response:

Significant differences in weed counts due to treatment effect were evident on both the August 3 and 18th sampling periods (Table 6.2). The use of excelsior resulted in green foxtail plant numbers being increased by 75-150% over that where no surface cover was provided (Treatment 2 vs. 4). This was unexpected; however, due to the unusually hot and dry weather it can be suggested that the excelsior shaded the soil surface thus preventing soil evaporation losses which were experienced in treatment #2. The competitive effect or allelopathic response of Canola reduced the plant density (Treatments 1 and 3 vs. 2). This was not noticeable on the August 3 sampling but was significantly apparent on the later August 18 date. No apparent differences between "clipping" or "wicking" could be detected in either weed counts/m^2 or dry matter produced (Treatment 1 vs. 3). Dry matter production in treatment #1 and 3 was severely curtailed when compared to the remaining two treatments. As with weed counts the production of dry matter was significantly greater (65%) where excelsior was applied versus where no ground cover was provided (Treatment 2 vs. 4). Weight per plant was very similar between treatments 1 and 3 as it was between treatments 2 and 4.

Table 6.2. The effect of canola management on green foxtail (Setaria viridis) growth and dry matter production - 1988.

Treatment[1]		Weed count #/m² August 3	Weed count #/m² August 18	% of control	Weed dry matter[2] (g/m²)	% of control	Weight/plant[3] (g)	% of control
Chopped Canola	1	35.4 a	34.2 a	40.5	1.0 a	1.5	0.03 a	3.8
Weeds only	2	49.0 a	84.4 b	100.0	65.8 b	100.0	0.78 b	100.0
Canola +2,4-D	3	27.0 a	25.6 a	30.3	0.4 a	0.6	0.02 a	2.5
Weeds excelsior	4	125.6 b	146.4 c	173.5	109.3 c	166.1	0.75 b	96.2
	X	59.3	72.7		44.1		0.50	
	L.S.D.	27.8	23.5		19.5		0.27	

1 - Treatments replicated 5 times in an RCBD
2 - Harvested August 18, 1988
3 - Determined on August 18, 1988

Means followed by the same letter within a column are not significantly different at P=0.05 NDMRT.

B. Kochia (Kochia scoparia) Response:

In relationship to the other two weed species kochia was slow to establish. This species however did respond in a similar fashion to green foxtail when excelsior was applied (Table 6.3). Plant counts were 50% greater with the excelsior product (Treatment 2 vs. 4). Dry matter production, as measured on August 18 revealed that there was however no significant difference between these two treatments. The reduced number of kochia plants present in treatment #2 compensated by producing increased biomass. Plant numbers present in treatment #1 and 3 did not differ significantly at either recording date. In addition the dry

matter produced between these two treatments was very similar. It was visually observed that "wicking" (Treatment 3) had a detrimental effect on the growth of existing kochia plants even though no herbicide physically contacted them. The plant weights in treatment #3 were 4X less than those recorded in the "clipping" plots (Treatment 1). In evaluating a similar comparison involving green foxtail or wild oat differences of this magnitude did not occur. It should however be noted that green foxtail or wild oat being grass species would not be sensitive to 2,4-D. Kochia while not physically contacted by the herbicide may have been exposed to herbicidal vapors from the product.

Table 6.3. The effect of canola management on kochia (Kochia scoparia) growth and dry matter production - 1988.

Treatment[1]	#	Weed count #/m^2 August 3	Weed count #/m^2 August 18	% of control	Weed dry matter g/m^2	% of control	Weight/plant[3] (g)	% of control
Chopped canola	1	7.8 a	8.2 a	80	0.9 a	1.1	0.10 a	1.2
Weeds only	2	10.2 a	10.2 a	100	82.6 b	100.0	8.09 b	100.0
Canola + 2,4-D	3	8.0 a	9.2 a	90	0.2 a	0.2	0.02 a	0.2
Weeds + excelsior	4	14.6 b	14.8 b	145	95.8 b	115.9	6.47 b	80.0
X		10.2	10.6		44.9		3.67	
L.S.D.		3.2	3.8		26.2		2.64	

1 - Treatments replicated 5 times in an RCBD
2 - Harvested August 18, 1988
3 - Determined on August 18, 1988

Means followed by the same letter within a column are not significantly different at P=0.05 NDMRT.

C. Tame Oat (Avena sativa) Response:

The tame oat responded to the various treatments in a somewhat different manner than the previously discussed species. When excelsior was applied it did not positively influence plant counts (Treatment 2 vs. 4) (Table 6.4). This was true for both sampling dates. Dry matter production was likewise not significantly changed between these two treatments. Significant differences in plant counts between treatment #1 and 4 were evident at the August 18 sampling date. The "clipping" plot (Treatment #1) did not control the tame oat population as well as "wicking" (Treatment #3). It should however be noted that in the "wicking" treatment a certain amount of the treated canola remained standing in the plot. This could have offered a "light" competition factor to the tame oat which would not have occurred in the "clipped" treatment. No significant difference in dry matter or plant weight occurred between these two treatments. In comparison to the other plant species discussed the tame oat weight/plant was least affected by any treatment.

Table 6.4. The effect of canola management on tame oat (Avena sativa) growth and dry matter production - 1988.

Treatment[1]		Weed count #/m² August 3	Weed count #/m² August 18	% of control	Weed dry matter g/m²	% of control	Weight/plant[3] (g)	% of control
Chopped canola	1	26.2 a	41.6 a	118	17.9 a	12.4	0.43 a	10.5
Weeds only	2	40.6 b	35.2 b	100	144.5 b	100.0	4.11 b	100.0
Canola + 2,4-D	3	30.8 a	31.8 b	90	7.4 a	4.7	0.23 a	5.6
Weeds + excelsior	4	40.6 b	31.4 b	89	156.0 b	108.0	4.97 b	120.9
X		34.6	35.0		81.4		2.44	
L.S.D.		9.2	5.2		16.5		1.41	

1 - Treatments replicated 5 times in an RCBD
2 - Harvested August 18, 1988
3 - Determined August 18, 1988

Means followed by the same letter within a column are not significantly different at P=0.05 NDMRT.

1989 Field Trials

Materials and Methods

Location: Kernen Crop Research Farm. L.S.D.: 8-37 4-W3-NW 1/4

Soil Association: Orthic Dark Brown Chernozemic - Sutherland clay loam

Experimental Design: The study was arranged as a randomized complete block design replicated 6 times. Each replicate contained 15 treatments consisting of 3 weed species, Green Foxtail (Setaria viridis), Kochia (Kochia scoparia) and Tame oat (Avena sativa) each managed using 5 methods (Table 6.5).

Individual plot size was 1 x 1 m with 2 m borders between treatments. Following hand seeding of the canola (Treatment 1 and 4) the crop was allowed to germinate and grow to the cotyledon leaf stage at which time all plots were seeded with one of the selected weed species. At this stage treatment #5 had excelsior applied (2 tonnes ha^{-1}). Excelsior was held in place by nylon fish netting to prevent wind or applied water from disturbing the material. Plots were regularly rogued to preclude foreign plant species from interfering with specific treatment growth. The study was irrigated on June 23 and July 21, 25 to prevent moisture stress from interfering with the final results. Soil profile moisture was maintained at 50-75% of field capacity to a depth of approximately 10 cm.

Table 6.5. Allelopathy Treatments - 1989.

Treatment #	Management Procedures[1]
1	Canola plants (20 cm height) clipped at ground level with aerial residue left to decay on soil surface. Weed growth not disturbed.
2	No canola plants present, only pure stand of either Green foxtail, Kochia or Tame oat.
3	Light shading[2] provided on pure weed stands of either Green foxtail, Kochia or Tame oat. No canola plants present.
4	Canola plants (20 cm height) killed by an application of 2,4-D (I.V. ester) @ 560 gai ha^{-1} using a "Wick" applicator. This method of application prevented any herbicide from contacting undergrowing weed species. Treated plant material left in plot area.
5	Excelsior applied at a rate of 2 tonnes ha^{-1} immediately following weed seeding. No Canola plants present. Any growth consisted of pure stand of either Green foxtail, Kochia or Tame oat.

1 - Only designated species were allowed to grow in this study. All other plants were removed by hand roguing.
2 - Cages of lath and plastic ribbon lattice were placed over these plots to reduce light levels to an estimated one-half of open field levels. (Light levels were not measured.)

Canola Allelopathy Field Operations - 1989

Work Procedure	Date
Pre seeding tillage operation on 1989 plot area.	May 27
Planted 1988 plot area to Katepwa hard red spring wheat.	May 29
Plot area watered to supply 2.5 cm ha^{-1} precipitation equivalent. (1989 study).	June 23
Canola seeded (12 kg ha^{-1} or 1.2 g/m^2) in required treatments.	June 26
Plant emergence and weed counts conducted on 1988 study.	June 27
Tame oat treatments seeded (22 seeds/m^2 - 92% germination).	June 30
Kochia (25 seeds/m^2 - 80% germination) and Green foxtail (250 seeds/m^2 - 90% germination) seeded.	June 30
Excelsior applied (2 tonnes ha^{-1}) to required treatments.	June 30
Carbofuran applied to Canola treatments for Flea beatle control.	July 4
Plot area watered to supply 2.5 cm.ha^{-1} precipitation equivalent (1989 study).	July 6
Light shading treatments applied on required treatments.	July 10
Foreign plant material rogued from plot area.	July 12
Plot area watered to supply 1.5 cm.ha^{-1} precipitation equivalent.	July 21
Plot area watered to supply 2.5 cm.ha^{-1} precipitation.	July 25
Foreign plant material rogued from plot area	July 27
Herbicide application of 2,4-D (560 gai ha^{-1}) "wicked" required canola plots.	August 4
Canola clipped at ground level.	August 4
Weed counts (#/m^2) determined (1988 study).	August 23
Weed counts (#/m^2) determined (1989 study).	August 24
Dry matter (g/m^2) determinations on treatments containing Tame oat, Kochia and Green foxtail (1988 study)	August 24
Spring wheat yield determinations (1988 study)	August 30

Results and Discussions. 1989 Results

A. Green Foxtail (Setaria viridis):

Significant differences in weed dry matter was recorded between the various treatments (Table 6.6). In comparison to the check treatment the excelsior did not result in any apparent difference in total plant dry weight or individual plant weight (Treatment 2 vs 5). The competitive or allelopathic response of canola as in 1988 again reduced both the total dry matter produced as well as the individual plant weight (Treatments 1 and 4 vs. 2). As in 1988 no differences between "clipping" or wicking could be detected. Shading, as provided in treatment #3 had a detrimental effect on growth statistically equal to either "clipping" or "wicking". Since this species is a C4 plant the reduction of photosynthetic light energy due to shading would be expected to have a marked effect. In comparison to the 1988 study total dry matter produced was increased by a factor of 5-6 fold.

Table 6.6. The effect of canola management on green foxtail growth and dry matter production - 1989.

Treatment[1]	Plant count (#/m^2)	% of control	Plant dry matter g/m^2	% of control	Weight/plant[3] (g)	% of control
1. Chop canola	93	80.2	171 b	34.1	1.84 b	42.5
2. Control	116 a	100.0	502 a	100.0	4.33 a	100.0
3. Shade	77 a	66.4	156 b	31.1	2.03 b	46.9
4. 2,4-D + canola	70 a	60.3	114 b	22.7	1.63 b	37.6
5. Excelsior	124	106.9	524 a	104.4	4.23 a	97.7
X	96		293		2.81	
L.S.D.	66		127		1.92	
c.v. (%)	46		39		42	

Means followed by the same letter within a column are not significantly different at P>0.05 NDMER.

B. Kochia (Kochia scoparia):

Kochia requires higher than normal temperatures to obtain optimum germination. During 1988, following seeding, conditions were hot and dry, favoring emergence and growth of this C-4 plant. In 1989 growing conditions during June were noticeably cooler with above average precipitation. Cooler temperatures of this nature resulted in erratic and low germination of this species. This was particularly noticeable in treatments where competition from canola (Treatments 1 and 4) (Table 6.7) occurred. In situations of this nature the number of plants present on the August 24, 1989 evaluation date was 1/3 to 1/2 of the 1988 study.

This species responded to the treatments in a similar fashion to green foxtail with the highest plant counts, dry matter production and individual plant weight occurring in the check and excelsior plots (Treatments 1 and 5). It was interesting to observe that the excelsior treatment did produce fewer plants and significantly lower dry matter yields than the check. The "clipped" and "wicked" treatments both had similarly low plant counts, dry matter production and individual plant weights. As in 1988 these two treatments severely restricted the growth and establishment of kochia. Shading had no detrimental effect on plant counts,however it did decrease dry matter production and individual plant weights.

Table 6.7. The effect of canola management on kochia (Kochia scoparia) growth and dry matter production - 1989.

Treatment[1]	Plant count (#/m^2)	% of control	Plant dry matter g/m^2	% of control	Weight/plant[3] (g)	% of control
1. Chop canola	2.2 b	25.1	13 c	2.5	5.91 a	10.0
2. Control	8.7 a	100.0	514 a	100.0	59.08 b	100.0
3. Shade	8.8 a	101.1	80 c	15.6	9.09 a	15.4
4. 2,4-D canola	4.5 b	52.2	22 c	4.3	4.88 a	8.3
5. Excelsior	5.3 ab	60.1	413 b	80.4	77.92 b	131.9
X	5.9		208		31.4	
L.S.D.	3.6		89		24.7	
c.v. (%)	50		39		43	

Means followed by the same letter within a column are not significantly different at P>0.05 NDMRT.

C. Tame Oat (Avena sativa):

Significantly different levels of dry matter production occurred depending on the specific treatment. The use of excelsior (Treatment 5) as in 1988, resulted in the greatest amount of biomass production (Table 6.8). Plots involving shading produced approximately 50% less dry matter when compared to either the check or excelsior (Treatment 3 vs. 2 and 5). Clipping or wicking (Treatments 1 and 4) severely restricted the amount of plant growth occurring. In comparison to the check treatment the wicked plot produced 85% less vegetative crop. This comparison would be very similar for one developed between the clipped plot and the check. Individual plant weights were lowest in the clipping and wicked plots (Treatments 1 and 4) and highest in the excelsior and check treatments 2 and 5. The lowest plant count was observed in the wicked treatment while most other showed no significant differences.

Table 6.8. The effect of canola management on Tame oat (Avena sativa) growth and dry matter production - 1989.

Treatment[1]	Plant count (#/m^2)	% of control	Plant dry matter g/m^2	% of control	Weight/plant[3] (g)	% of control
1. Chop canola	14.3 ab	91.1	39 d	17.2	2.73 a	18.9
2. Control	15.7 a	100.0	227 b	100.0	14.46 b	100.0
3. Shade	15.3 a	97.5	128 c	56.4	8.37 ab	57.9
4. 2,4-D canola	11.0 b	70.1	28 d	12.3	2.55 a	17.6
5. Excelsior	16.8 a	107.0	279 a	122.9	16.61 b	114.9
X	14.6		144		8.9	
L.S.D.	3.3		34		10.3	
c.v. (%)	18		23		20	

Means followed by the letter within a column are not significantly different at P=0.05 NDMRT.

The Effect of Preceding Canola Residue and Weed Management Practices on Succeeding Spring Wheat Yields

During the initial year of the above study each of the following management practices was applied to 3 weed species, green foxtail, kochia and tame oat.

Allelopathy Treatments

Treatment #	1988 Management Procedures[1]
1	Canola plants (20 cm height) clipped at ground level aerial residue left to decay on soil surface. Weed growth not disturbed.
2	No canola plants present, only pure stand of either green foxtail, kochia or tame oat.
3	Canola plants (20 cm height) killed by an application of 2,4-D (L.V. ester) @ 560 gai ha^{-1} using a "Wick" applicator. This method of application prevented any herbicide from contacting undergrowing weed species. Treated plant material left in plot area.
4	Excelsior applied at a rate of 2 tonnes ha^{-1} immediately following weed seeding. No canola plants present. Any growth consisted of pure stand of either green foxtail, kochia or tame oat.

1 - Only designated species were allowed to grow in this study. All other plants were removed by hand roguing.

In year 2 (1989), the above treatments were seeded to Katepwa hard red spring wheat on May 29. The following grain yields were recorded (Table 6.9).

Table 6.9. The effect of preceding canola and weed management on spring wheat yields in 1989.

Treatment	Wheat Grain Yield Previous weed species					
	Green foxtail		Kochia		Tame oat	
	g/m^2	% of control	g/m^2	% of control	g/m^2	% of control
1. chop canola	227	104	200	91	199	109
2. control	219	100	219	100	183	100
3. 2,4-D canola	251	115	187	85	185	101
4. Excelsior	208	95	197	90	198	108
X	226		200		191	
L.S.D.	N.S.		N.S.		N.S.	
c.v. (%)	17		19		23	

No significant differences in grain yield occurred between any of the previous treatments or weed species. In addition to the above parameter the number of wheat plants per square meter was observed. Depending on the treatment, 141-165 plants/m^2 were recorded. As with yield, no significant differences occurred related to this property.

Summary of the Two Years of Field Trials

The executive summary at the beginning of this report gives our conclusions about the field trials to date. That section of the report is repeated here so as to round out the results from the field and suggest future directions for research and development.

The results from these two years of trials are shown in Table 6.10.

Table 6.10. Effect of canola cover crop on the growth (weight per unit) area of three weeds.

Weed	Treatment	1988	1989
		weeds weight as a % of control	
Green Foxtail	Chopped canola	1.5 a	34.1 a
	* Canola killed with 2,4-5	0.6 a	22.7 a
	Control (weed only)	100.0 b	100.0 b
	Control plus poplar mulch	166.1 c	104.0 b
	Control plus shading	ND	31.1 a
Kochia	Chopped canola	1.1 a	2.5 a
	Canola killed with 2,4-D	0.2 a	4.3 a
	Control (weed only)	100.0 b	100.0 c
	Control plus poplar mulch	115.9 b	80.4 b
	Control plus shading	ND	
Oats (Tame oats to mimic wild oats)	Chopped canola	12.4 a	17.2 a
	* Canola killed with 2,4-D	4.7 a	12.3 a
	Control (weed only)	100.0 b	100.0 c
	Control plus poplar mulch	108.0 b	122.9 d
	Control plus shading	ND	56.4 b

ND = not determined
Note: the smaller the number the better the control of the weed.
* Note: The 2,4-D applied to the canola would not directly effect the foxtail or oats.

Numbers followed by the same letter within a column and within a weed species are not significantly different at P=0.05 NDMRT.

The years 1988 and 1989 offered a complete contrast in growing conditions. In 1988 the spring and early summer were so hot and dry that we waited until late June to plant the canola and the weeds. Then in July the weather improved; temperature were only slightly above normal and rainfall slightly below normal. In August the weather was cooler and rainier than normal. The canola established well and formed a canopy over the weeds. Killing the canola gave excellent control of green foxtail and kochia, and good control of oats (simulating wild

oats). In 1989 we waited until late June to plant the canola and then the weeds to repeat the comparison with 1988. But July and early August in 1989 were hotter and drier than in 1988. The weeds were able to compete with the canola better under these conditions, particularly green foxtail. Control of kochia was still very good in 1989, but control of oats was slightly poorer, and of green foxtail only fair. In both years the degree of weed control by the canola was statistically significant.

The lesson we have learned from the 1989 results is that it is important to get the canola cover crop well established (e.g. early spring) before the weeds emerge in order to obtain good weed control. This needs to be tested in further field trials. The 1989 results also indicate that shading of the weeds can reduce growth significantly also, another reason to get the cover crop established early.

Other experiments in the growth room have shown that chemicals released by the killed canola or mustard are likely responsible for at least some of the weed suppressing effects we have found. This chemical effect seems to be integrated with other weed suppressing effects such as shading and competition for nutrients and moisture between the cover crop and the weed. A number of other experiments need to be carried out to measure the relative importance of the different effects.

Wheat was grown in 1989 on the plots from the 1988 cover crop experiments. No differences in yield were found, showing that there were no negative effects of the cover crops carrying over from 1988 to 1989.

Where Do We Go from Here?

The best situation to test these very promising results would, we think, be to use canola as a cover crop for summer fallow. Canola or mustard ar cheap to seed. If they were planted early and killed by mulching or by 2,4-D when they were still young in late June or early July, the moisture loss from the cover crop growth might be regained from the mulch effect and snow trapping over the following winter. Many other experiments and field trials are needed to measure the effect on many other weeds and on other following crops. We do not know whether any of the natural herbicides being released from the cover crop into the environment have a negative effect on man or other living creatures; this will also need to be examined.

Canola or mustard might be useful in situations other than as a cover crop for fallow. Frank Forcella at the USDA research centre in Morris, Minnesota found that young canola could be used as an over-wintered cover crop to kill weeds in a continuous zero-till corn production system. The spring-growth of the canola was killed with 2, 4-D just before the corn was zero-till planted. Corn yields were as good as the control, weed control was nearly as good as the conventional system using several herbicides, and overall weed control costs were one-half those of the conventional system (Forcella, 1986). We used some of his ideas in developing our own experiments here in Saskatchewan.

Farmers attempting to reduce or eliminate herbicides may find such cover crops of use to them in the future. As far as we can determine, the use of such natural herbicide containing cover crops, once they are

proven safe, would not contravene the guidelines for organic crop certification, provided mulching was used to kill the cover crop.

For farm situations where herbicides are used, combinations of herbicides with these cover crops might be less likely to lead to inadvertent selection for weeds with herbicide resistance. It is unlikely that the weed population would contain plants with the genes for both allelopathic chemical resistance and herbicide resistance.

We stress that our results are in the early stages of development into farm proven systems, although the initial results are very encouraging. We are looking forward to further studies to develop sustainable cropping systems involving natural herbicide containing cover crops.

References

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Meyer, D.W., 1987. Sweetclover: an alternative to fallow for set-aside acreage in eastern North Dakota Agriculture, March-April, p. 3-8, 13.

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APPENDIX

SASKATCHEWAN RESEARCH COUNCIL
CLIMATE REFERENCE STATION
LOCATION: 52°09'N 106°36'W 497 m MSL
MONTHLY WEATHER SUMMARY FOR
MAY 1989

Element	1989 Value	1988 Value	Mean or Extreme Value 1951-1980[2]	Extreme All Years[3]
Monthly Mean Temperature[4] (°C)	11.5	15.5	11.2	
Monthly Mean Maximum Temperature[5] (°C)	18.1	23.5	18.1	
Monthly Mean Minimum Temperature[6] (°C)	4.8	7.5	4.3	
Extreme Maximum Temperature[7] (°C)	27.5	35.0	34.0	37.2
Year/Day(s)[20]	1989/7&10	1988/30	1980/21	1936/27
Years of Record[21]	1	1	17	92
Extreme Minimum Temperature[7] (°C)	-6.5	-1.0	-10.0	-12.8
Year/Day(s)[20]	1989/5	1988/2	1967/2	1907/6
Years of Record[21]	1	1	17	92
Days with Frost[8]	3	1	6	
Heating Degree-Days[9] (18°C base)	190.0	101.5	216.0	
Growing Degree-Days[10] (5°C base)	188.5	316.5	199.0	
Total Precipitation[11] (mm)	88.4	14.1	39.6	
Total Rainfall[11] (mm)	88.4	14.1	37.7	
Total Snowfall[12] (cm)	0.0	0.0	1.8	
Greatest 24-hour Precipitation (mm)	21.0	5.6	33.8	51.3
Year/Day(s)[20]	1989/12	1988/29	1975/19	1909/30
Years of Record[21]	1	1	17	92
Greatest 24-hour Rainfall (mm)	21.0	5.6	33.8	51.3
Year/Day(s)[20]	1989/12	1988/29	1975/19	1909/30
Years of Record[21]	1	1	17	92
Greatest 24-hour Snowfall (cm)	0	0	4.3	26.2
Year/Day(s)[20]	--	--	1969/14	1983/10
Years of Record[21]	1	1	17	92
Precipitation Days[13]	19	6	7	
Rainfall Days[13]	19	6	1	
Snowfall Days[13]	0	0	7	
Total Evaporation[14] (mm)	190.8	276.0	208.7	
Mean Wind Speed[15] (km/hr)	29.6	14.8*	19.4	
Peak Gust Speed[16] (km/hr)	87	63	132	
Total Bright Sunshine[17] (hr)	272.7	263**	292	
Percent Possible Bright Sunshine[18]	56	54	60	
Total Global Radiation[19] (MJ m^{-2})	636.2	603	659	
Total Diffuse Radiation[19] (MJ m^{-2})	201.0	228	--	
Mean Soil Temperature[22] (°C) (10, 50 cm)	10.7, 10.1	14.5, 11.2	12.3, 8.8	
Mean Soil Temperature[22] (°C) (150, 300 cm)	5.3, 3.5	5.6, 3.9	4.1, 2.9	

*6 days missing data
**includes automated data (May 1-25)

SUMMARY MAY 1989 - Revised Version

May 1989 started out looking like a repeat of last May. Up until the 11th there had only been 1.5 mm of precipitation, a dust storm on the 10th and fairly high daily temperatures. On the 11th it started to rain, and rain it did, so that by the 25th of May the Climate Reference Station had received 85.9 mm of precipitation. By May 31st the total recorded precipitation was 88.4 mm, 223% of normal. The mean monthly temperature was near normal at 11.5°C. The mean maximum temperature equalled the normal value of 18.1°C, while the mean minimum temperature was 4.8°C. There were fewer heating and growing degree days than normal by 18 and 10.5 respectively. The evaporation (190.8 mm) was below normal and well below last year's value of 276.0 mm. There was a high mean wind speed in May with a value of 29.6 km/hr and a maximum of 87 km/hr on the 10th; the same day that there was reduced visibility due to blowing dust. The amount of bright sunshine was less than normal by 19 hours. The soil temperatures were all below last year's values but when they are compared, the mean values of the 10 cm depth was 1.6° cooler than normal, the 50 cm was 1.3° warmer, the 150 cm depth was 1.2° warmer and the 300 cm depth was 0.6°C warmer.

May 1989 brought the precipitation amount up to be 69% normal for the year. As the saying "it never rains but it pours" was certainly applicable this month.

SASKATCHEWAN RESEARCH COUNCIL
CLIMATE REFERENCE STATION
LOCATION: 52°09'N 106°36'W 497 m MSL
MONTHLY WEATHER SUMMARY FOR
JUNE, 1989

Element	1989 Value	1988 Value	Mean or Extreme Value 1951-1980[2]	Extreme All Years[3]
Monthly Mean Temperature[4] (°C)	16.9	21.3	15.6	
Monthly Mean Maximum Temperature[5] (°C)	23.5	28.8	22.1	
Monthly Mean Minimum Temperature[6] (°C)	10.3	13.8	9.1	
Extreme Maximum Temperature[7] (°C)	34.0	41.0	35.6	41.0
Year/Day(s)[20]	1989/30th	1988/5th	1976/4	1988/5th
Years of Record[21]	1	1	17	93
Extreme Minimum Temperature[7] (°C)	3.5	4.0	-3.3	-3.9
Year/Day(s)[20]	1989/13th	1988/15	1967/6	1903/9 & 1917/2
Years of Record[21]	1	1	17	93
Days with Frost[9]	0	0	0	
Heating Degree-Days[9] (18°C base)	63.5	15.0	89.0	
Growing Degree-Days[10] (5°C base)	351.5	495.0	319.0	
Total Precipitation[11] (mm)	63.5	23.7	59.9	
Total Rainfall[11] (mm)	63.5	23.7	59.9	
Total Snowfall[12] (cm)	0	0	0	
Greatest 24-hour Precipitation (mm)	30.0	11.0	45.0	99.4
Year/Day(s)[20]	1989/25	1988/29	1970/10	1983/24
Years of Record[21]	1	1	17	93
Greatest 24-hour Rainfall (mm)	30.0	11.0	45.0	99.4
Year/Day(s)[20]	1989/25	1988/29	1970/10	1983/24
Years of Record[21]	1	1	17	93
Greatest 24-hour Snowfall (cm)	0	-	0	1.8
Year/Day(s)[20]	-	-	-	1938/29
Years of Record[21]	-	-	17	93
Precipitation Days[13]	7	10	11	
Rainfall Days[13]	7	10	11	
Snowfall Days[13]	0	0	0	
Total Evaporation[14] (mm)	214.2[a]	352.1	218.3	
Mean Wind Speed[15] (km/hr)	27.9	16.5[b]	18.2	
Peak Gust Speed[16] (km/hr)	89	68	101	
Total Bright Sunshine[17] (hr)	262.6	323.1	294.0	
Percent Possible Bright Sunshine[18]	53	65	59	
Total Global Radiation[19] (MJ m^{-2})	690.4	685	683	
Total Diffuse Radiation[19] (MJ m^{-2})	234.1	167	-	
Mean Soil Temperature[22] (°C) (10, 50 cm)	15.4, 14.3	21.0, 17.2	17.5, 14.0	
Mean Soil Temperature[22] (°C) (150, 300 cm)	8.4, 5.4	9.5, 6.0	8.3, 5.2	

[b] 6 days missing data
[a] 1 day missing data

SUMMARY:

June 1989 was what could be termed as typical. The mean maximum, mean minimum and mean temperatures were all about one degree above the normal recorded values. The highest the temperature reached this month was only 34°C (rather low compared to last year's record of 41°C) and the lowest temperature recorded was 3.5°C. The overnight lows were never very low because of the large amount of cloud cover. The number of heating degree days was 25.5 less than normal but much higher than the 15.0 that was recorded last year. The number of growing degree days was 32.5 greater than the mean, but 143.5 less than last years high value. The amount of precipitation received was greater than normal for the second month in a row. This year to date has received 204.4 mm of precipitation as compared to the normal value of 187.7 mm. The greatest one day rainfall occurred on Sunday the 25th when 30.0 mm fell. The amount of evaporation was about the same as normal but well below last year's value by over 140 mm. June was once again fairly windy with a mean wind speed of 27.9 km/h and a maximum gust recorded at 89 km/hr on the last day of the month. The amount of bright sunshine was 32 hours below the mean value and 60.5 hours below last year's sunny hot month. The soil temperatures were all above the mean value except for the 10 cm depth which was 2.1°C below.

June 1989, with its large amount of rainfall, was not a good month for keeping the car clean, but it did make the crop (and weeds) in the Saskatoon area grow very well.

SASKATCHEWAN RESEARCH COUNCIL
CLIMATE REFERENCE STATION
LOCATION: 52°09'N 108°36'W 497 m MSL
MONTHLY WEATHER SUMMARY FOR

JULY, 1989

Element	1989 Value	1988 Value	Mean or Extreme Value 1951-1980[2]	Extreme - All Years[3]
Monthly Mean Temperature[4] (°C)	20.0	19.2	18.4	
Monthly Mean Maximum Temperature[5] (°C)	27.3	26.6	25.2	
Monthly Mean Minimum Temperature[6] (°C)	12.8	11.7	11.6	
Extreme Maximum Temperature[7] (°C)	37.0	37.0	36.7	40.0
Year/Day(s)[20]	1989/21st	1988/22nd	1964/12	1919/17;1941/19
Years of Record[21]	1	1	17	93
Extreme Minimum Temperature[7] (°C)	8.0	16.0	1.7	-0.6
Year/Day(s)[20]	1989/13th	1988/9th	1967/2	1910/25
Years of Record[21]	1	1	17	93
Days with Frost[8]	0	0	0	0
Heating Degree-Days[9] (18°C base)	12.0	16.5	32.3	
Growing Degree-Days[10] (5°C base)	463.5	451.5	416.3	
Total Precipitation[11] (mm)	27.8	47	56.2	
Total Rainfall[11] (mm)	27.8	47	56.2	
Total Snowfall[12] (cm)	0.0	0.0	0.0	
Greatest 24-hour Precipitation (mm)	11.5	25.1	45.5	79.2
Year/Day(s)[20]	1989/10th	1988/6th	1968/29	1946/3
Years of Record[21]	1	1	17	93
Greatest 24-hour Rainfall (mm)	11.5	25.1	45.5	79.2
Year/Day(s)[20]	1989/10th	1988/6th	1968/29	1946/3
Years of Record[21]	1	1	17	93
Greatest 24-hour Snowfall (cm)	0.0	0.0	0.0	0.0
Year/Day(s)[20]	--	--	--	--
Years of Record[21]	1	1	17	--
Precipitation Days[13]	5	7	11	
Rainfall Days[13]	5	7	11	
Snowfall Days[13]	0	0	0	
Total Evaporation[14] (mm)	261.6	290.7	230.1	
Mean Wind Speed[15] (km/hr)	24.3	14.8	16.7	
Peak Gust Speed[16] (km/hr)	79	M	105	
Total Bright Sunshine[17] (hr)	328.8	336.5	341.0	
Percent Possible Bright Sunshine[18]	65.6	67.1	68	
Total Global Radiation[19] (MJ m^{-2})	628.2[a]	661.1	737	
Total Diffuse Radiation[19] (MJ m^{-2})	201.2[a]	195.1	--	
Mean Soil Temperature[22] (°C) (10, 50 cm)	19.4, 18.0	18.2, 17.9	19.7, 16.9	
Mean Soil Temperature[22] (°C) (150, 300 cm)	11.3, 7.4	11.5, 8.6	11.4, 7.6	

[a] 4 days missing data M data missing

SUMMARY:

July 1989 was a hot dry month. This was the first month since April 1989 that below normal precipitation was recorded. The Climate Reference Station recorded 27.8 mm of precipitation, below half of the normal value of 56.2 mm. The January to July total precipitation was only 11.7 mm below normal. Above normal temperatures were recorded this month. The mean monthly temperature of 20.0°C was 1.6°C above the normal value. The mean maximum temperature was 2.1°C above the normal and the mean monthly minimum was 1.2°C above. The extreme maximum, recorded on the 21st, equalled last years temperatures of 37°C, while the mean minimum was quite cool at 8.0°C recorded on the 13th. The high temperatures allowed for a significant number of growing degree days (463.5), well above the normal of 416.3. In contrast, the number of heating degree days were lower than normal by 20.3 days. The total evaporation of 261.6 mm was approximately 30 mm more than the normal but was 29.1 mm less than last year's evaporation rate. July 1989 was also very windy. The mean wind speed was 24.2 km/hr, with a peak gust of 79 km/hr occurring on the 30th of the month. July had only 65.6% of the total possible sunshine. The 10 and 50 cm soil temperatures were above the value recorded last year but the temperatures at the 150 and 300 cm depths were below by 0.2°C and 1.2°C respectively.

The hot dry weather of July 1989, reminded everyone of the kind of weather we had last year.

Virginia Wittrock
Research Technologist

SASKATCHEWAN RESEARCH COUNCIL

CLIMATE REFERENCE STATION

LOCATION: 52°09'N 106°36'W 497 m MSL

MONTHLY WEATHER SUMMARY FOR

AUGUST 1989

Element	1989 Value	1988 Value	Mean or Extreme Value 1951-1980[2]	Extreme All Years[3]
Monthly Mean Temperature[4] (°C)	18.5	16.8	17.2	
Monthly Mean Maximum Temperature[5] (°C)	25.1	22.4	24.2	
Monthly Mean Minimum Temperature[6] (°C)	11.8	11.1	10.2	
Extreme Maximum Temperature[7] (°C)	35.0	31.0	36.7	37.8
Year/Day(s)[20]	1989/1st	1988/13th	1970/7	1393/6, 1949/6
Years of Record[21]	1	1	17	92
Extreme Minimum Temperature[7] (°C)	6.0	3.0	-2.8	-2.8
Year/Day(s)[20]	1989/20th	1988/28th	1976/28	1976/28
Years of Record[21]	1	1	17	92
Days with Frost[8]	0	0	0	
Heating Degree-Days[9] (18°C base)	45.5	49.5	60.1	
Growing Degree-Days[10] (5°C base)	412.0	371.5	370.7	
Total Precipitation[11] (mm)	58.6	78.2	35.1	
Total Rainfall[11] (mm)	58.6	78.2	35.1	
Total Snowfall[12] (cm)	0.0	0.0	0.0	
Greatest 24-hour Precipitation (mm)	27.9	20.4	24.6	73.7
Year/Day(s)[20]	1989/25th	1988/1st	1963/18	1945/3
Years of Record[21]	1	1	17	92
Greatest 24-hour Rainfall (mm)	27.9	20.4	24.6	73.7
Year/Day(s)[20]	1989/25th	1988/1st	1968/18	1945/3
Years of Record[21]	1	1	17	92
Greatest 24-hour Snowfall (cm)	0.0	0.0	0.0	0.0
Year/Day(s)[20]	-	-	-	-
Years of Record[21]	1	1	17	
Precipitation Days[13]	9	11	10	
Rainfall Days[13]	9	11	10	
Snowfall Days[13]	0	0	0	
Total Evaporation[14] (mm)	218.0	195.4	201.4	
Mean Wind Speed[15] (km/hr)	24.1	M	16.5	
Peak Gust Speed[16] (km/hr)	70	72	151	
Total Bright Sunshine[17] (hr)	252.9	238.1	293.0	
Percent Possible Bright Sunshine[18]	56	53	65	
Total Global Radiation[19] (MJ m^{-2})	583.1	516.2	605.0	
Total Diffuse Radiation[19] (MJ m^{-2})	240.0	143.9	-	
Mean Soil Temperature[22] (°C) (10, 50 cm)	17.6, 18.0	17.7, 16.6	18.4, 16.7	
Mean Soil Temperature[22] (°C) (150, 300 cm)	12.8, 9.2	12.1, 11.9	12.6, 9.3	

M data missing

SUMMARY:

August 1989 had above normal temperatures and above normal precipitation. The monthly mean temperature was 1.3°C above normal while the monthly mean maximum and the monthly mean minimum were 0.9°C and 1.6°C above normal. The high temperatures led to a low heating degree day value of 45.5 and a high growing degree day value of 412.0. The amount of precipitation that fell was 58.6 mm, 23.5 mm above normal. So far this year, to the end of August, Saskatoon has received 290.8 mm of precipitation compared to last year's 225.1 mm. The normal amount of precipitation to the end of August is 279.0 mm. The total amount of evaporation at 218.0 mm was greater than normal. The mean wind speed of 24.1 km/h was also fairly high. The peak gust was only 70 km/h, which is well below the maximum ever recorded of 151 km/h. The amount of total bright sunshine was 252.9 h, above last year's amount, but below the long term average. Total global radiation was 583.2 MJ m-2, while the total diffuse radiation was 240.0 MJ m-2. The 10 cm and the 300 cm mean soil temperatures were both below normal and below last year's values. The 50 cm and 150 cm mean soil temperature were above the normal and last year's temperatures.

August 1989 will be remembered by farmers as a month that was not very conducive to combining. It rained 11 days, in varying amounts, out of the last 16 days of the month.

Virginia Wittrock, Research Technologist